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THE AMERICAN WELDING SOCIETY JOURNAL

VOLUME 15 SEPTEMBER 1936 NUMBER 9

PUBLISHED MONTHLY FOR THE ADVANCEMENT OF THE SCIENCE AND ART OF WELDING

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THE metal man's annual opportunity to hear and discuss the work of outstanding experts in the metal industry, is provided at the National Metal Congress, to be held this year in Cleveland, October 19 through 23.

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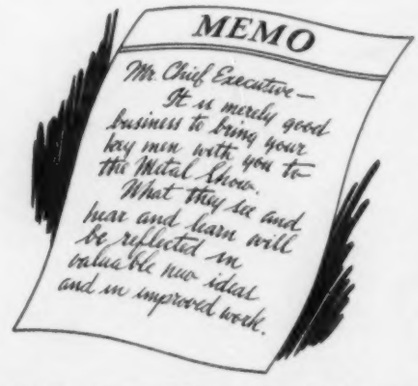
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● For complete details, write W. H. Eisenman, Managing Director, National Metal Congress & Exposition, 7016 Euclid Ave., Cleveland, O.

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CLEVELAND, OHIO — PUBLIC AUDITORIUM — OCTOBER 19-23, 1936

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ISSUED MONTHLY

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Welding of Aircraft Structures*

By J. B. JOHNSON†

Aeronautical Industry.—The aeronautical industry has successfully adapted welding to the construction and maintenance of airplanes, engines and accessories. The economical use of material to achieve low weight in the structure requires a number of sizes and gages; consequently, a multiplicity of joints. The characteristics and reliability of welded joints were determined by laboratory and service tests and the results have been applied to the design and fabrication of aircraft operating under all conditions. Welding has been used successfully for the smallest sport airplane and the largest transports. The welded joint has the advantage of simplicity, rigidity and relatively high strength since no metal is removed for rivet or bolt holes. There is no deterioration if it is properly protected against corrosion. Materials which can be easily welded to obtain a high joint efficiency have been developed and standardized.

Welding Processes.—The types of welding which have been used extensively in the aeronautical industry are:

A. Gas welding.
  1. Oxyacetylene.
  2. Oxyhydrogen.
B. Direct current electric arc welding.
C. Electric resistance welding.
  1. Flash welding.
  2. Spot welding.
D. Atomic hydrogen welding.

Oxyacetylene Welding.—The oxyacetylene process is the most flexible type. It is adaptable to the welding of ferrous and non-ferrous parts of the lightest and the heaviest sections used in airplane construction. It is used for joining the several structural parts of the airplane, such as wings, fuselage, control surfaces and landing gears, for engine jackets, exhaust manifolds, tanks and hard surfacing of tail skids and engine valves.

The equipment is similar to that used in other industries. Manufacturers have studied the needs of the industry and developed torches of both the pressure and injector types, weighing only a few ounces, which can be conveniently manipulated in restricted places and used continuously without tiring the welder. The technique of the welder varies to some extent depending upon his skill and previous training, but in general a small neutral flame, which avoids heating too large an area of base metal, gives the most satisfactory joint.

Oxyhydrogen Welding.—The oxyhydrogen process is used for welding aluminum and the non-heat-treatable aluminum alloys for the manufacture of fuel, oil and water tanks, fairing, and other miscellaneous low stressed parts. The lower temperature of the oxyhydrogen flame requires the use of a flame larger than that used with oxyacetylene and generally produces a seam with a smoother surface and a more gradual contour. The selection of hydrogen or acetylene is a matter of shop practice and training of operators as extensive service tests of fuel and oil tanks indicate no superiority for either type of welding.

Electric Arc Welding.—Electric arc welding has been used for joining carbon and alloy steels but not for non-ferrous metals. It has been applied principally to the welding of structural parts such as fuselages, landing chassis and control surfaces. It has been used satisfactorily for metal as thin as 0.031 inch but only by the most skilful welders.

Direct current metallic arc welding is used exclusively. The welding machines have a capacity of about 200 amperes and are equipped with special devices to obtain the maximum control of currents of low amperage which are required for the thin metal. The bead formed by arc welding is heavier and has a more irregular surface than the oxyacetylene bead, which is a disadvantage for close fitting parts. The penetration is greater, and metal up to $^3/_{32}$ inch in thickness will indicate a bead on both sides of the seam. A cross section of typical welds in $^1/_{16}$-inch tubing is shown in Fig. 1. The narrower zone affected by the welding heat is considered an advantage for arc welding. This is graphically shown by the hardness survey of the three types of plain butt welded joints taken on sections of welded joints in chrome-molybdenum tubing of $^1/_{16}$ inch wall thickness, Fig. 2*a*, and the compression test specimens, Fig. 2*b*. The width of the zone has no measurable effect on the ultimate strength of the member.

Electric Resistance Welding.—Electric resistance welding has been used to a limited extent in the form of (*a*) flash welding for simple butt joints, and (*b*) spot welding for corrosion-resistant steels and aluminum and aluminum alloys. Flash welded joints have been used in engine mounts and tubular axles for butt joints of tubes and forgings, Fig. 3. Equipment for flash welding is similar to that used in other industries. Due to the

* A contribution for the proposed Welding Handbook of the AMERICAN WELDING SOCIETY. Constructive criticism is invited.

† Chief, Material Branch, War Department, Air Corps.

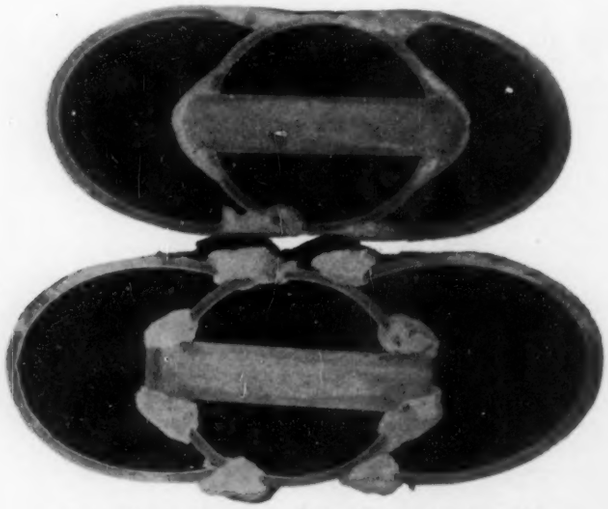


Fig. 1—Upper—Oxyacetylene Weld. Lower—D.C. Arc Weld

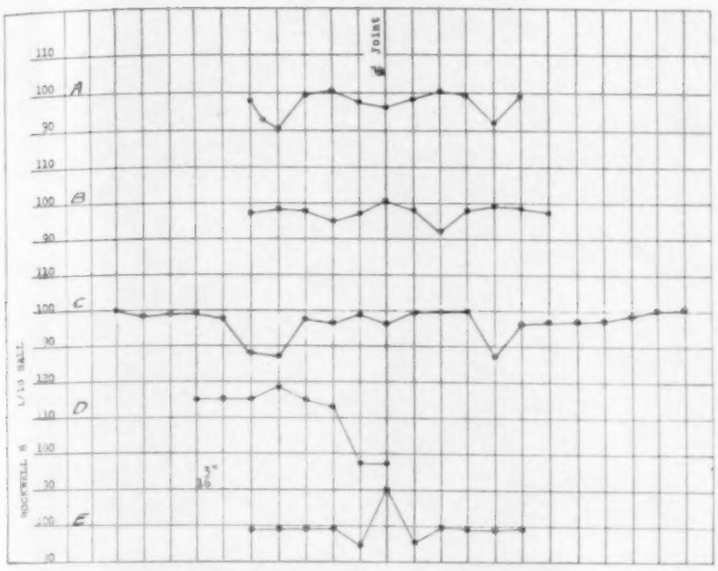


Fig. 2a—Butt Welds, Steel No. X-4130 — 1 x 0.065 Tubing.

A. Oxyacetylene
B. D.C. Arc
C. Oxyacetylene, Heated 1625° F. Air Cool
D. " " " " Oil Quench
E. Flash resistance Draw 900 deg.

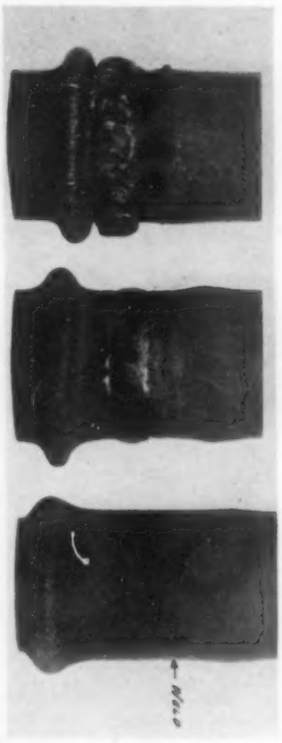


Fig. 2b

relatively small production of any single airplane design it has had only a very limited application. Flash welded joints have a very narrow zone affected by the heat of welding, Fig. 2*a*, which is hot worked when the pressure is applied. This probably accounts for their relatively high fatigue strength, Table 2.

Spot welding was tried several years ago for small fittings and structures built of heat-treated alloy steel strip, and was discontinued on account of the erratic

Table 1—Aviation Materials—Ferrous

Material	Specifications U. S. Army	Specifications U. S. Navy	Chemical Composition Carbon	Manganese	Silicon	Nickel	Chromium	Molybdenum	Other Elements	Tensile Prop. (Min.) Ult. Str. Kips	Y.S. Kips	Elon. 2 In. Per Cent	Rad. Area Per Cent
Carbon Steel (1025) Sheet	57-136-3	47S17	0.20 0.30	0.50 0.80	..	..	..	..	....	55	36	22	
Carbon Steel (1025) Bar	57-107-9	46S22	0.20 0.30	0.50 0.80	..	..	..	..	....	55	36	22	
Carbon Steel (1025) Tube	57-180-1	49T1	0.20 0.30	0.50 0.80	..	..	..	..	....	55	36	22	
Chrome-Molybdenum (X-4130) Sheet	57-136-8	47S14	0.25 0.35	0.40 0.60	..	..	0.80 1.10	0.15 0.25	....	... 90	... 70	10[1] 15	
Chrome-Molybdenum (X-4130) Bar	57-107-19	46S23	0.25 0.35	0.40 0.60	..	..	0.80 1.10	0.15 0.25	....	125	100	18[5]	
Chrome-Molybdenum (X-4130) Tube	57-180-2	44T18	0.25 0.35	0.40 0.60	..	..	0.80 1.10	0.15 0.25	....	90 95	70 75	15[1] 10	
Chrome-Molybdenum (4140) Bar	10083	....	0.35 0.45	0.50 0.80	0.15 0.30	..	0.80 1.10	0.15 0.25	....	... 125	... 100	.. 18[5]	
3½ Nickel (2330) Bar	57-107-17	46S21	0.25 0.35	0.50 0.80	0.15 0.35	3.25 3.75	.. ..	.. ..	....	125	100	17	50[5]
Chrome-Vanadium (6130) Sheet	57-136-7	47S12	0.25 0.35	0.50 0.80	..	..	0.80 1.10	.. ..	Va 0.15	... ...	... ...	.. ..	
Chrome-Nickel (18-8) Sheet	57-136-9	47S19	0.07[2]	0.20 0.70	.. 0.70[2]	8 10	17 20	.. ..	Ti[3]	80	35	40	
Chrome-Nickel (18-8) Sheet	11068	S73	0.15	0.70	0.70	7[2]	17[2]	..	....	125 185	90 150	10 5	
Chrome-Nickel (18-8) Bar	10079	46S18	0.20	0.20 0.70	.. ..	7 10	17 20	.. ..	....	80 125	35 100	35 12	50[4] 25
Chrome-Nickel (18-8) Tube	57-180-3 57-180-4	44T25	0.07	0.20 0.70	.. 0.70	8 11.5	17 20	.. ..	.... Ti	80 185	35 140	50[4] 8	
Corrosion-Resistant (2 Ply)	10081	....	0.08	0.20 0.70	.. 0.70	8 10	17 20	..[6] ..	....	... 60	... ...	.. 40	
Chrome-Nickel Forgings	.....	....	0.40 0.50	0.70	0.30 0.80	13 15	13 15	.. 0.50	V 1.75 3.0	... ...	... ...	.. ..	

[1] Varies with thickness. [2] Maximum. [3] 5.5 × effective carbon (actual C-0.02). [4] Several tempers available. [5] After heat treatment. [6] Backing is carbon steel.

Table 1—Non-Ferrous

Material	Federal Specifications Bar	Federal Specifications Sheet	Tube	Copper	Silicon	Aluminum	Manganese	Iron	Magnesium	Nickel	Chromium	Tensile Net[4] Strength Kips
Aluminum	QQ-A-411	QQ-A-561	WW-T-783			99						14.5–22
Aluminum-Manganese	QQ-A-356	QQ-A-359	44-T-20[1]			97	1.25					14.5–27
Aluminum-Magnesium-Chromium	.....	.....	47A-11[1]			96			2.5		0.25	31–39
Aluminum-Copper-Magnesium	QQ-A-351	QQ-A-353	WW-T-786	4		92	0.7		0.5			35–55
Magnesium Alclad		57-152-2(2)				92	0.7		0.5			30–50
Aluminum-Copper-Magnesium 1.5	11071[3]	11066	10235	4.2		92	0.6		1.5			35–65
Magnesium Alclad		11067[3]		4.2		92	0.6		1.5			32–58
Aluminum-Silicon	Castings		57–72[3]		5	93						19
Magnesium-Aluminum						4	0.3		94			35–48
Copper-Nickel (Monel)		QQ-C-541		23	0.5	0.5	3.5	3.5	..	60		80–110
Nickel-Chromium-Iron		10082[3]		0.5	0.4	..	1.25	9	..	75	10	85–125
Copper-Silicon		11065[3]		95	3.0	..	1	...	..	..	..	55

[1] U. S. Navy. [2] U. S. Army. [3] Air Corps. [4] Tensile strength varies with size, cold work and heat treatment.

Table 2—Fatigue Characteristics of Welded Steel Tubes

Size of specimen—1 inch O.D. × 1/16 inch wall thickness

Type of Joint	Material: Base Metal	Material: Filler Metal	Heat Treatment after Welding	Tensile Strength Joint[1] Kips	Fatigue Limit Kips: Base Metal	Fatigue Limit Kips: Welded Joint	Ratio[2]
Butt-Oxyacetylene	1025	Low carbon	None	50	30	13	0.43
Butt-D.C. Arc	1025	Medium carbon	None	50	30	14	0.47
Butt-Atomic Hydrogen	1025	1025	None	50	30	16	0.53
Fish Mouth-Oxyacetylene[3]	1025	Low carbon	None	55	30	16	0.53
Butt-Oxyacetylene	X-4130	Low carbon	None	95	41	16	0.39
Butt-Flash	X-4130	None	None	100	41	24	0.59
Butt-Oxyacetylene	X-4130	Low carbon	950° F.—30 min.	95	41	18	0.44
Butt-Flash	X-4130	None	950° F.—30 min.	103	41	32	0.78
Butt-Oxyacetylene	X-4130	Low carbon	1650° F.—30 min.	90	..	16	..
Butt-Oxyacetylene	X-4130	Cr-Mo	None	95	41	18	0.44
Butt-Oxyacetylene	18.8	18.8	None	85	24	16	0.67
Butt-Oxyacetylene	18.8	18.8	1600° F.—30 min.	84	24	23	0.96
Butt-Oxyacetylene	18.8	18.8	2000° F.—30 min.	81	..	16	..

[1] Calculated on area of base metal. [2] Welded Joint ÷ Base Metal. [3] Telescoping tube 7/8 inch O.D. × 1/16-inch wall thickness.

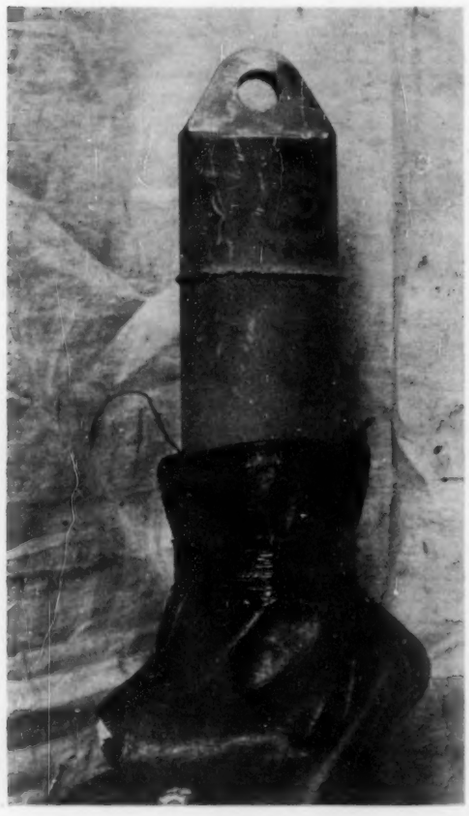


Fig. 3—Tail Wheel Fitting, Flash Welded

and unreliable results due to inadequate equipment, and the characteristics of the material. The development of mechanical and electrical devices for controlling the timing of the period for the passage of the current has improved this condition. Machines which automatically control the time in which the pressure and current are applied have brought about a high degree of uniformity in the strength and ductility of the spots. The principal field for spot welding is the fabrication of structural parts from thin sheets of corrosion-resistant steels containing 18% chromium, 8% nickel, and for containers, flooring, ammunition chutes, seats, fairing and other non-structural parts fabricated from aluminum alloys. The heat is applied for such a short period and small area that the original physical properties are not affected outside the spot and warping is not serious. The power required depends upon the material to be welded and is much greater for aluminum alloys than for steel. A spot welding machine with a throat with a 6-in. gap and 30-in. depth will require a nominal capacity of 300 kva. to weld aluminum alloy sheets up to approximately 0.093 in. in thickness. Accurate timing is required since insufficient current will not properly fuse the two surfaces in contact and too heavy currents cause cracks and blow-holes in the spots which affect the ductility and fatigue resistance although the shearing strength may not be reduced.

Atomic Hydrogen Welding.—Atomic hydrogen welding was investigated as a process for general application to the welding of airplane structures but was not adopted as a production process on account of the bulkiness of the

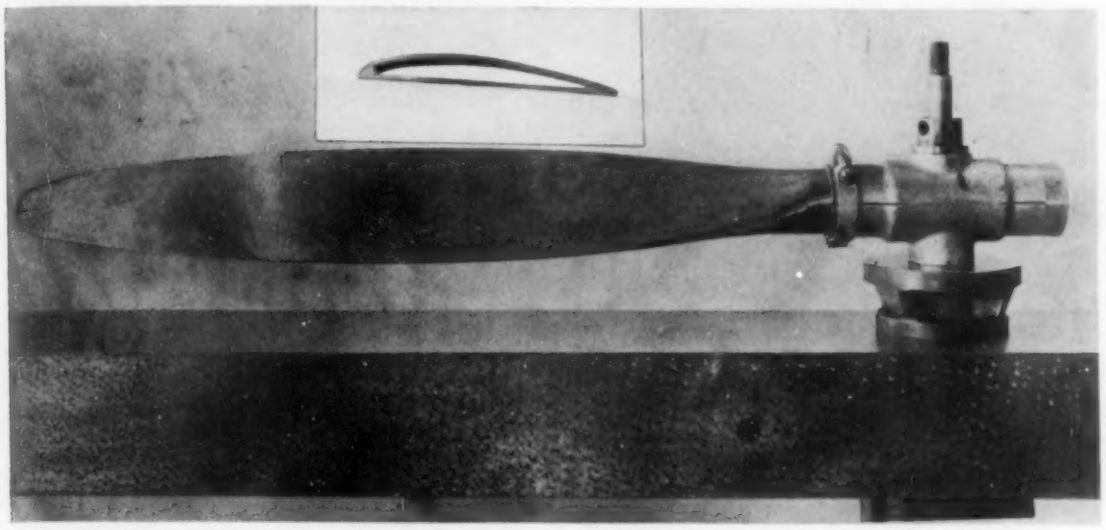


Fig. 4—Welding Steel Propeller

equipment which made it difficult to weld in restricted places, and the fact that the oxyacetylene process has given uniformly satisfactory results. It has found a field in the welding of accessories, such as the welded steel propeller, Fig. 4. The weld metal has a greater ductility than that deposited by either the oxyacetylene flame or electric arc, which is an advantage in a structure subject to large deflections.

Materials.—The materials which are used by the aeronautical engineer for welded parts are listed in Table 1. Plain carbon steel has been largely replaced by chrome-molybdenum steel for the more highly stressed structures and fittings on account of its greater strength in the normalized condition and capacity for heat-treatment. This chemical composition was selected primarily on account of the ease with which it could be welded and the fact that it had air hardening properties in thin sections which permitted a higher allowable stress in "as welded" joints than in the case of other low alloy steels. The manganese was restricted to a maximum of 0.60 as several lots which contained a higher content exhibited low ductility in tensile and bend tests of welded joints. The tensile properties after heating to 1625° F., quenching in oil and drawing, are indicated in Fig. 5. These are nominal values taken from results obtained with the standard $^1/_2$-inch test specimen heat treated in the form of 1-inch round bars. Thin sheets and tubes will generally have higher tensile properties for equal drawing temperatures. The elongation is a function of the shape of the test specimen and the relationship established in U. S. Army Specification 98-10025 for a sheet metal specimen with 2-inch gage length and $^1/_2$-inch width is given in the three lower curves. The chrome-molybdenum steel, No. 4140, is used for parts containing thick sections which would require quenching in water if made from X-4130. Fusion welding of this steel is not recommended except in special cases and should be followed by a heat treatment. Three and one-half per cent nickel steel is used for screw machine parts, gears and small forgings. Welding of this steel is confined to relatively low stressed joints. Chrome-vanadium steel is used in the welded steel propeller.

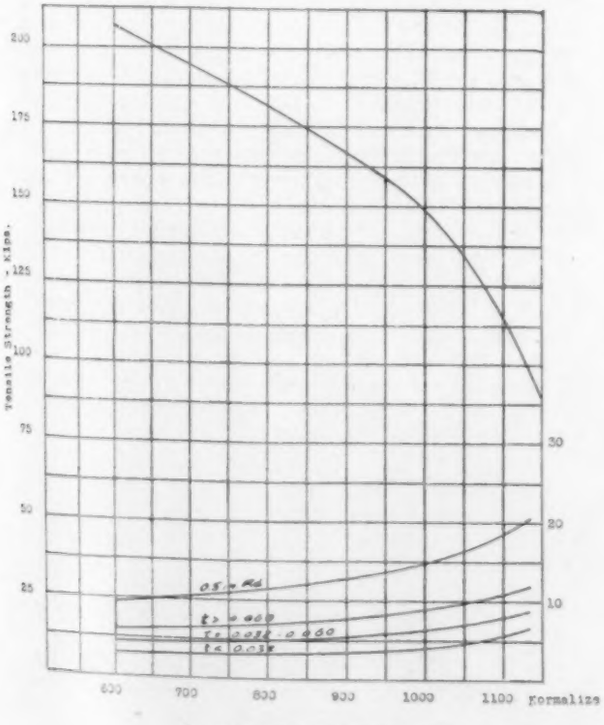


Fig. 5

The stainless steels are used in the annealed condition for exhaust stacks, tanks and structures which are required to be non-magnetic. The steel can be fusion welded with either the oxyacetylene flame or electric arc. Tanks and containers are spot welded. The fusion welding of this steel to chrome-molybdenum is not recommended as the joints may be brittle. This steel cannot be heat-treated to raise the physical properties but cold work is very effective. High tensile cold rolled sheets

Table 3

Sheet Thickness Inches	Sample No.	Welding Data Time Sec.	Welding Data Electrode Pressure Pounds	Average Strength Pounds Before Exposure	Average Strength Pounds After Exposure
0.005	92	0.050	75	600	500
0.010	72	0.066	150	1800	1920
0.015	63	0.083	150	2350	2380
0.020	63	0.116	125	2370	2550
0.026	72	0.133	175	4290	4370

Sample number denotes spot arrangement, e.g., 92 is 9 spots in 2 rows.

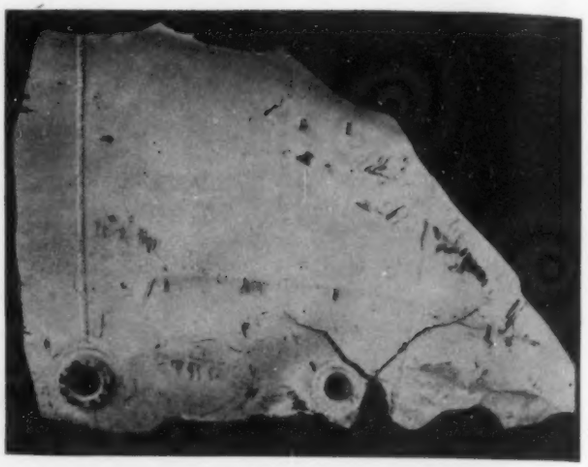


Fig. 6 (Left)—Magnesium Alloy Seat

Fig. 6a (Above)—Section from Magnesium Alloy Gondola Broken by a Free Fall of Several Hundred Feet

and strips are used for structures, fittings and miscellaneous parts.

The selection of the 18 and 8 steel for exhaust stacks and manifolds which operate at from 1000 to 1600° F. has greatly reduced the formation of scale and the corrosion from the products of combustion of gasoline containing tetraethyl lead. Titanium and columbium act as stabilizing elements and reduce the tendency to develop intercrystalline embrittlement which had been found in the stacks after approximately 100 hours' service.

The cold rolled material cannot be fusion welded very satisfactorily on account of warping but is easily spot welded. The material resists salt water corrosion and the spot welds, if properly manufactured without excessive heating of the metal around the spot, do not lower this resistance appreciably. The tests given in Table 3 were made on spot welded specimens of cold rolled (180,000 p.s.i.) strip without any subsequent cleaning or polishing. The test was conducted for 720 hours by alternately immersing the specimens for 1 minute in a 20 per cent NaCl: water solution and drying 13 minutes in air at approximately 80° F. Visual examination indicated no pitting but a few spots of red iron oxide and small spots with a bright etched surface. Tests of pontoons, floats and wing structures demonstrate that these laboratory tests are an indication of the serviceability of the material for airplanes.

The 99 per cent aluminum is used extensively for fuel, oil, water tanks and cowling, but in a few cases the aluminum-manganese has been substituted on account of its greater strength. The aluminum-magnesium-chromium alloy is a non-heat-treatable alloy with relatively high strength for the same purposes. These materials are fusion welded with either acetylene or hydrogen. The heat-treatable alloys containing aluminum, copper and magnesium are rarely fusion welded on account of the loss in strength. The base metal can be reheat-treated after welding to its original strength but the effect on the weld metal is not so satisfactory. Spot welding of these alloys is a practical method. The joint may be heat-treated since the metal in the spot is fused under pressure and rapidly cooled, a condition which assists solution of the constituents at the heat treating temperature. The shearing strength of the spots is increased about 20 per cent by the normal heat-treatment for the base metal.

Exhaust valves for airplane engines are forged from an austenitic steel with a high resistance to corrosion. The wear of the seat and tip which is due to the inherent softness of this steel is overcome by hard surfacing with Stellite Nos. 1 and 6 applied with the oxyacetylene flame.

Nickel which is used for spark plug electrode tips is resistance welded to a carbon steel spindle.

Monel is used for special tanks and containers for corrosive liquids such as insecticides and smoke pro-

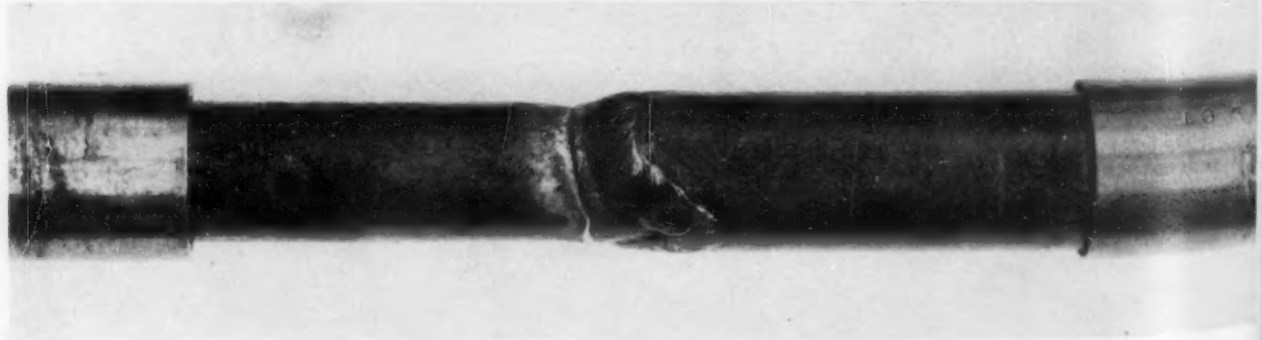


Fig. 7—Tensile Failure of Fish-Mouth Weld

Table 4—Welding Rod and Electrodes

Material	Federal Spec. No.	Chemical Composition Carbon	Manganese	Silicon	Nickel	Chromium	Other Elements
Rod, Low Carbon	QQ-W-351-Gr. E.	0.06	0.15	0.06	..	..	....
Rod, Chrome Molybdenum	....	0.30	0.80	..	..	1	Molybdenum 0.25
Rod, Chrome Vanadium	....	0.20	0.60	0.35	..	1	Vanadium 0.23
Rod, Chrome Nickel	10297[1]	0.10	0.40	..	9	19	0.70
Rod, Special	....	0.15	1	0.50	..	..	....
Rod, Stellite No. 1	10300[1]	..	..	..	..	32	Tungsten 12. Cobalt 45
Rod, Stellite No. 6	10300	..	..	..	..	30	Tungsten 4. Cobalt 60
Electrodes, Carbon	QQ-W-351-Gr. B	0.15	0.50	0.06	..	..	....
Electrodes, Carbon	....	0.18	0.75	0.50	..	..	....
Aluminum	QQ-R-571 Type D	..	..	..	..	..	Aluminum 99
Aluminum Alloy	QQ-R-571 Type E	..	..	5	..	..	Aluminum 92.5
Copper-Silicon	....	..	0.75	0.15	..	..	Copper 60. Zinc remainder

[1] U. S. Army Air Corps.

Type	Tension and Compression[1] Allowable Unit Stress Base Metal Lb./Sq. In. 1025	X-4130
Butt	45,000	80,000
Scarf	50,000	90,000
Fish Mouth	50,000	90,000
Tee	35,000	55,000
Tee with Gussets	45,000	75,000
Lattice	35,000	60,000
Lattice with Plate	40,000	75,000

[1] Member of trusses loaded as columns seldom develop the full allowable compressive strength of the material. Gussets and plates increase the end restraint but an end fixity constant of 2.0 is general practice for simple tees as well as reinforced joints.

Fig. 8

ducing chemicals. Inconel is a material which has high strength at elevated temperatures without embrittlement and is resistant to lead bromide corrosion, which are desirable characteristics for exhaust stacks, supercharger housings, mufflers and cockpit heaters. These materials are generally welded with the oxyacetylene flame as the metal is thin and a small, smooth bead is desirable for telescoping and close fitting parts.

Copper-silicon is used for tanks, segregators and other ground equipment where weight saving is not so important and resistance to corrosion is essential.

Magnesium alloys with a weight equal to two-thirds of the aluminum alloys can be joined by electric spot welding or by oxyacetylene welding. An application for spot welding is the seat shown in Fig. 6. The pieces of a gondola used for a stratosphere balloon which was demolished by a free fall of 3000 feet demonstrated the impact resistance of welded seams. The magnesium alloy ball was badly shattered with practically no failure of the seams (Fig. 6*a*).

Filler Metal.—Norway iron welding rod was specified originally by the majority of airplane builders but commercially pure iron and low carbon steel were substituted and found satisfactory. The chemical composition of several types of rods which have been used are given in Table 4. Low carbon steel, which is equivalent to the former A. W. S. Specification G-1-A, is used almost exclusively for carbon and chrome-molybdenum steels, although welding rods of alloy steel and high tensile steel are used in some cases to obtain a high unit strength in the deposited metal, especially for parts heat-treated after welding. A non-ferrous copper-zinc-silicon rod is used by some manufacturers as it has a lower melting point than the ferrous rods and there is less distortion of tubular members with thin walls. It is not recommended for highly stressed joints.

Stainless steel rod should contain some stabilizing element such as titanium or columbium. The latter is less liable to burn out during welding.

Aluminum rod or strips cut from sheet is the best for welding aluminum but the 5 per cent silicon-aluminum rod is preferred for the alloys both cast and wrought. Other non-ferrous alloys are generally welded with rod conforming to the analysis of the base metal.

Fluxes.—No flux is used in the oxyacetylene welding of carbon or low alloy steels, but in the case of arc welding an electrode with a thin coating of flux is practically essential for satisfactory welds.

Aluminum and magnesium base alloys require a flux which is a mixture of sodium, potassium and lithium chlorides with or without additions of sodium and potassium fluorides.

Corrosion-resistant steel and Inconel are welded more easily with a flux. A mixture of boron oxide, sodium oxide and silica is satisfactory. It is applied as a thin paste using a water solution of sodium silicate as a vehicle.

Design of Joints.—Individual joints for aircraft structures have generally been approved on a basis of breakdown tests on the manufactured joints. From this practice, data have been obtained which are used for new designs.

Fusion Welds.—The strength of a fusion welded joint will depend upon the unit strength of the weld metal, the base metal and the effect of heat of welding on the base metal unless the joint is heat-treated after welding. Joints made with plain butt welds, plain telescope or lap welds, tapered welds with angles greater than 30 degrees to the center-line or fish-mouth welds greater than 60 degrees are designed on the basis of a maximum value for the tensile strength of 80,000 p.s.i. in the case of chrome-molybdenum steel and 45,000 p.s.i. in the case of medium carbon steel.

Joints made with tapered welds at angles of 30 degrees or less to the center-line or fish-mouth welds with an

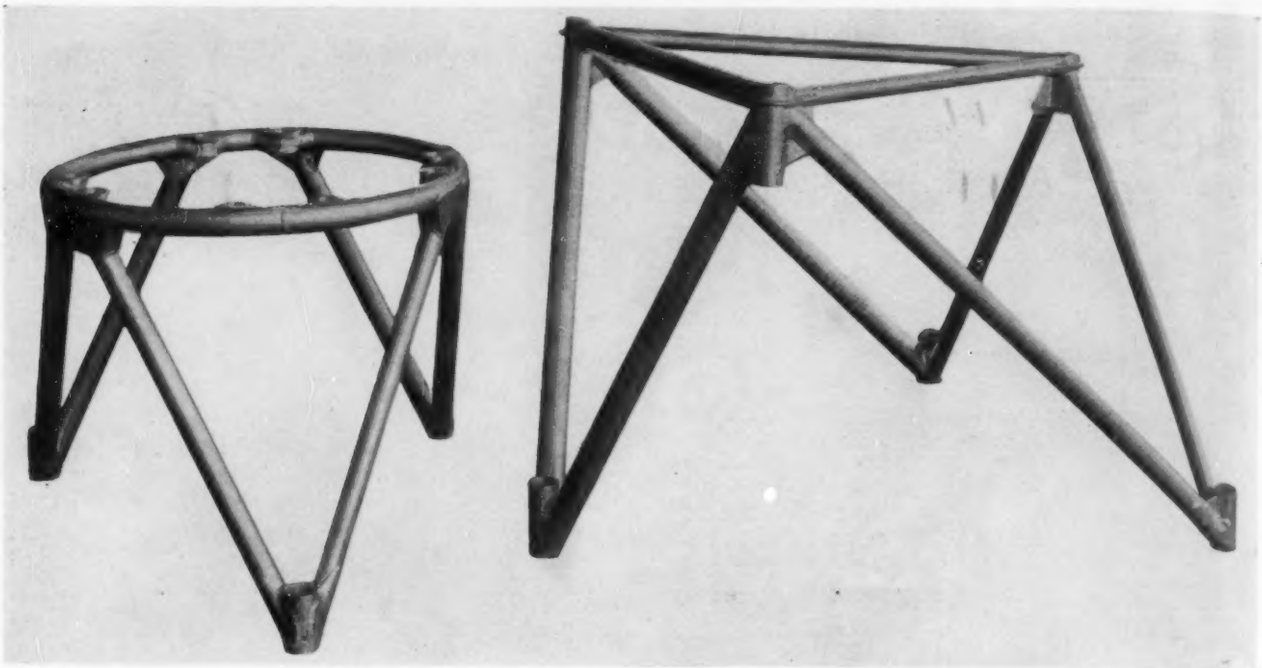


Fig. 9

included angle of 60 degrees or less are designed on a basis of a tensile strength of 90,000 p.s.i. for chrome-molybdenum steel and 50,000 p.s.i. for medium carbon. These joints invariably break in the base metal, as illustrated in Fig. 7 for a fish-mouth weld with an included angle of 60 degrees. These values are for the base metal of joints welded from steel conforming to the specifications, Table 1 or for heat-treated chrome-molybdenum steel welded after heat treatment. For joints welded and subsequently heat-treated the allowable stress may be taken as 80% of the strength of the heat-treated base metal.

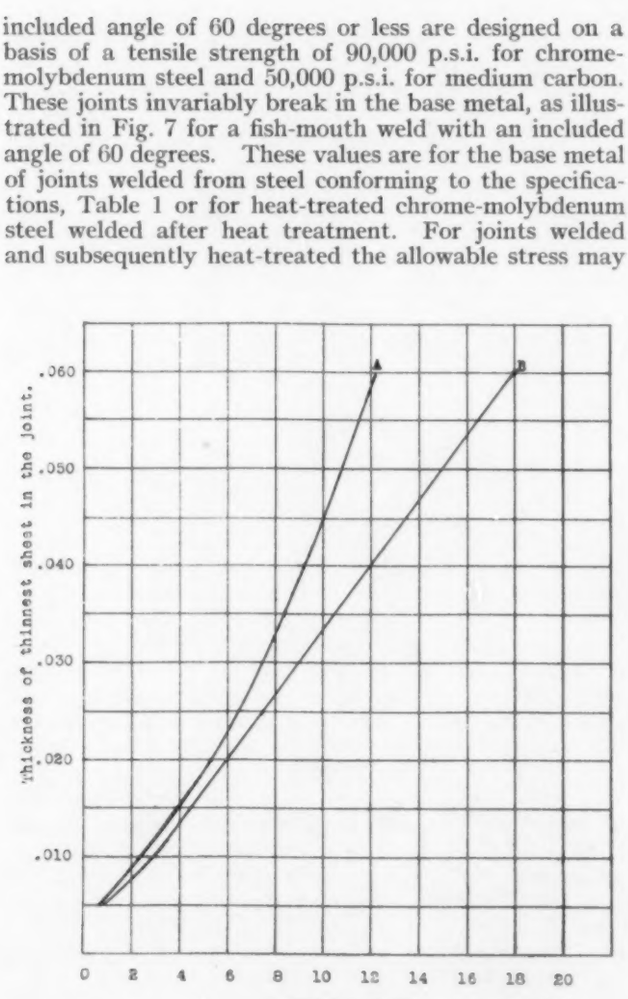


Fig. 10

The strength of the weld metal will depend upon the chemical composition of the filler rod. Table 5 was obtained from empirical data. It gives the strength of a welded seam in terms of its length in inches for several thicknesses of base metal. The filler rod in all cases was equivalent to No. 1, Table 4, except for the last column for joints heat-treated above 150,000 p.s.i. which is based on chrome-molybdenum filler rod. In case low carbon rod is used the values given in the column for 125,000 p.s.i. are satisfactory. The effect of increasing the length of the welded seams by the addition of gussets is shown in Fig. 8. The unit stresses represent average values obtained by testing the joints in tension; the supports and application of the load, *P*, are indicated by arrows. Reinforcing plates also stiffen the joints, affording a means of avoiding a sharp concentration of stress at the end of a vibrating member and give greater end fixity for numbers serving as columns in a truss. The engine mounts, Fig. 9, illustrate joints which have been used successfully to absorb vibration.

Practices Which the Designer of Fusion Welds Should Avoid: (*a*) A joint between very thin and heavy metal, as the heat required to bring the heavier metal up to the welding temperature may burn or melt away the thin metal.

(*b*) The convergence of more than six members to form a welded cluster. The repeated applications of

Table 5—Calculated Strength Per Inch of Seam—Pounds
(Reinforced weld equal to $1^1/_2 \times$ thickness of stock)

Thickness of Stock (Inches)	Unit Strength Base Metal			
	Carbon 55,000	Chrome-Molybdenum 90,000	125,000	150,000 and 200,000
$^1/_{32}$	1000	1,400	1,800	2,300
$^1/_{16}$	2000	2,800	3,800	4,600
$^3/_{32}$	3000	4,200	5,600	6,900
$^1/_8$	4000	5,600	7,500	9,200
$^3/_{16}$	6000	8,400	11,200	13,800
$^1/_4$	8000	11,200	15,000	18,400

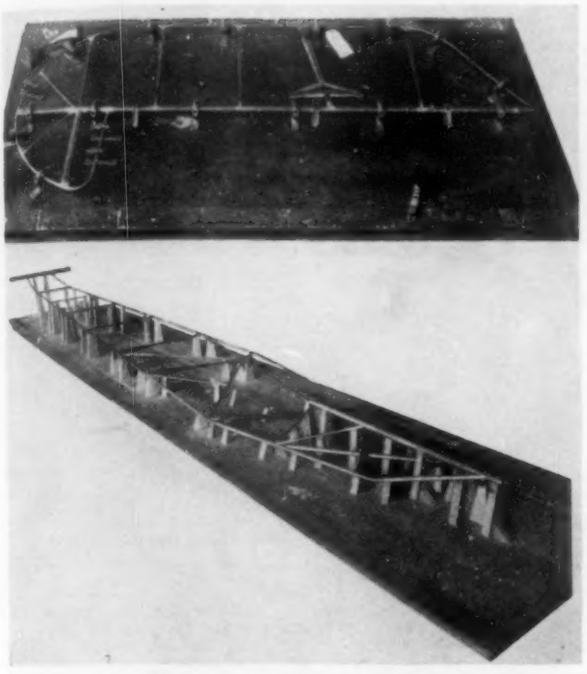


Fig. 11 (Upper)—Jig for Control Surface

Fig. 11a—Layout for Jig for Side of Fuselage

heat on the small area where all the members meet weakens the base metal adjacent to the remelted weld metal.

(*c*) The use of tin-lead solder in proximity to a joint so that a repair of the joint might cause contamination of the weld metal by the solder.

(*d*) Welding of a brazed joint. The reverse practice of brazing a welded joint is permissible.

(*e*) A joint which requires welding at the inside junction of two members forming an acute angle.

Spot Welds.—The strength of a spot-welded joint depends upon the composition and condition of the base metal, the strength of the individual spots and the number of spots and their spacing. Complete data for the several materials and tempers used in aircraft construction have not been obtained. Corrosion-resistant (18:8) steel, cold rolled to a tensile strength of 180,000 p.s.i. is used for airplane structures and surface covering, and design data have been obtained for this material in thin gages.

A design chart for joints fabricated from this material is given in Fig. 10, Curve *A*. The strength per spot decreases to a certain limit for each additional spot and this effect is greater as the spacing is reduced. The chart is based on a lap weld of seven spots per lineal inch arranged in two rows of 4 and 3 spots, respectively. This number of spots will develop the full strength of the base metal. Curve *B* represents the minimum values for single spot specimens.

Heat Treatment.—The heat treatment of welded airplane structures in order to relieve the residual stresses has not been practiced for fuselages, wings or control surfaces, and it is doubtful if any failures can be attributed to their presence. It has been done to a limited extent on engine mounts and large fittings. It should always be done on exhaust headers, rings and stacks in order to prevent distortion on reheating in service. Stress relief is carried out at approximately 1200 or 1650° F. for chrome-molybdenum steel, and 1575 to 1625° F. for the corrosion-resistant (18:8) steel followed by cooling in air. The fatigue resistance of the latter was appreciably increased by stress relief treatment, Table 2.

Heat treatment of welded structures by quenching and tempering is general practice for such parts as landing gear struts, tail wheel supports, center section struts, highly stressed sections of the fuselage and fittings. The use of jigs to support the members in the furnace and prevent distortion on quenching is good practice and essential in many cases. The time lag from the furnace to the quenching bath should be as short as possible. Building the furnace over the tank facilitates rapid quenching. Vents must be provided for the escape of air and vapor and the rapid circulation of the quenching medium inside of hollow members.

The tensile properties shown in the curve, Fig. 5, are applicable to thin tubular and sheet specimens cut from heat-treated structures, but the drawing temperature should be checked by tests on the actual parts heat-treated in accordance with the procedure to be used in production.

Manufacture.—The successful application of welding for the construction of parts which must be interchangeable and which are assembled into a structure requiring close alignment of all parts is made possible by the use of jigs and fixtures to hold the parts during welding. The design of jigs requires ingenuity and a knowledge of the laws of expansion and contraction of metal. Steel heated up to the welding heat has very little strength and ductility. A crack is easily formed by any stress due to warpage or contraction. The several parts for a welded assembly are cut to length and fitted so that there is a small clearance between the abutting members. This clearance should be as uniform as possible, e.g., in the case of a truss member welded into the sidewall of a tube, the end of the member should be milled to fit the contour of the tube. Jigs should be rigid and massive so that they will not warp due to the reflected or direct heat of the flame or arc.

Bench welding is usually more economical than floor welding and in the case of a fuselage structure some factories prefer to weld the side panels complete on the bench and simply weld the connecting bottom and top members on the floor jig. Another method is to hold the parts in a floor jig and starting at the tail post weld both sides of the fuselage simultaneously working forward toward the engine mount. Each joint is completely welded before starting the next consecutive joint.

Jigs need not be intricate, in fact many of them are made of boiler plate or structural steel with the guides and clamps welded to the base. An arc welder is very convenient for this purpose.

Some of the precautions to be observed in welding airplane parts are:

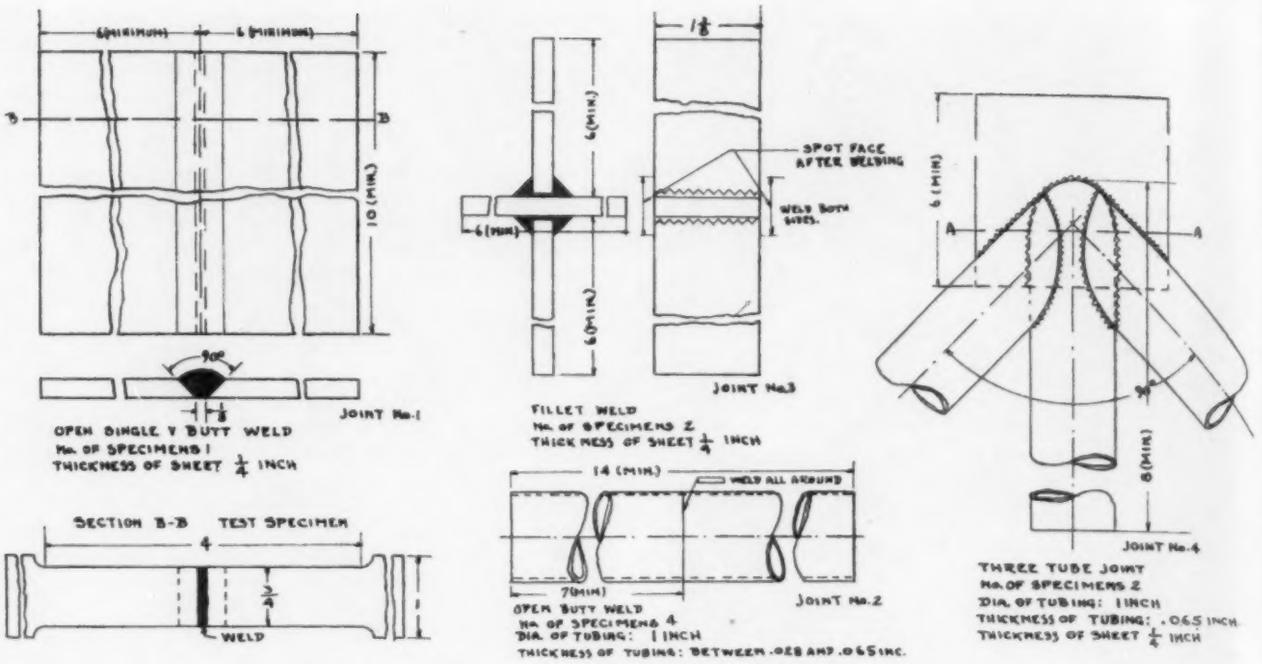
(*a*) It is preferable to start a weld away from the edge and weld toward it and thus reduce the liability of a crack at the edge.

(*b*) Welding should not be so rapid that the base metal is not actually melted and the weld metal is simply applied like a solder. This is the most prolific source of weld failures.

(*c*) Welding a joint consisting of thin and thick sections without properly preheating the thicker section. It may be necessary to apply some external heat to the heavy section other than that from the welding torch.

(*d*) The straightening of tubes which have warped, by applying heat on the convex side of the bend. This practice is sometimes necessary in making repairs but it is better practice to revamp the jig or change the sequence of welding so that the member will not be warped.

(*e*) The application of a torch or arc to a part heat-treated to a tensile strength exceeding 180,000 p.s.i.



QUALIFICATION TEST FOR AIRCRAFT WELDERS

Fig. 12

The part should be locally annealed if welding is to be done.

(*f*) The application of any tension, bending or twisting load on a joint at the welding heat due to warpage of the base metal, binding of the jig, or uncompensated contraction and expansion. A slight compression stress may be an advantage and prevent cracking.

Inspection of Welded Joints.—Visual examination of the welded joints by competent inspectors has been the method most generally adopted by airplane manufacturers for the inspection of fusion welds. This has been supplemented by qualification tests established by the U. S. Army Air Corps and Bureau of Aeronautics, Specifications 20013 and SR-14-A, respectively. These specifications require a certificate which is a record of the operator's experience, and qualification tests which consist of the manufacture of several types of joints. These joints are illustrated in Fig. 12.

Joint No. 1 is made with a single reinforcement. This reinforcement is machined off and the sample cut up into test specimens of the form and dimensions shown in Fig. 2. The tensile test is made on each sample. The average strength should not be less than 45,000 pounds per square inch for plain carbon steel and 70,000 pounds per square inch for alloy steel. This is primarily a test of the filler metal and the welding procedure may be recommended by the manufacturer.

Joint No. 2 is an open butt weld and specimens are made in a horizontal position, vertical position and an overhead position not lower than the welder's eyes. These joints are tested in tension without removing the reinforcement. The strength of the joint should not be less than 50,000 pounds per square inch for plain carbon steel and 80,000 pounds per square inch for alloy steel, calculated on the area of the base metal. This joint determines the welder's ability to weld tubular members in different positions.

Joint No. 3 is a right angle fillet weld which is tested in tension and should not develop less than 10,000 pounds per lineal inch for plain carbon steel and 15,000 pounds per lineal inch for alloy steel. Welders accustomed to making welds in thinner material find this joint difficult to manufacture because it requires skilful preheating of the base metal to obtain fusion in the corner but is typical of many joints in large fittings.

Joint No. 4 is a combination weld of sheet and tubes of light and heavy section. The welded seam between the sheet and tube should develop not less than 1500 pounds per lineal inch for plain carbon steel and 2500 pounds per lineal inch for alloy steel when tested in tension holding the plate and tube in the jaws of the testing machine. After the tension test, the specimen is cut at Section *A-A*, polished and etched with 50 per cent aqueous hydrochloric acid solution. (Fig. 1.) A visual examination of the weld indicates the character of the weld metal and the penetration. It has proved to be a practical method of demonstrating to the operator proper and improper methods of welding. An airplane fitting with a similar combination of parts may be substituted for this test fitting.

The practice of filling hollow sealed structures with hot linseed or petroleum base oils, under pressure, in order to coat the inside surface and inhibit corrosion, assists in the detection of cracks as the hot oil will seep through cracks invisible to the eye.

X-ray inspection has had only limited application on account of the inaccessibility of many joints and the necessity of taking exposures from several angles in order to be sure that the X-ray beam is parallel to the plane of the defect.

Magnetic inspection by means of magnetic powder such as magnaflux and black rouge has proved the most practical non-destructive method. It will indicate very fine hair-line cracks or small blow-holes. Equipment for examining welded steel propellers is shown in Fig. 13 with a pattern of the defects which were present in some of the first propellers and which were eliminated by applying the magnaflux inspection as a shop control process for detecting defects and thus improving welding technique. The surface to be examined should be

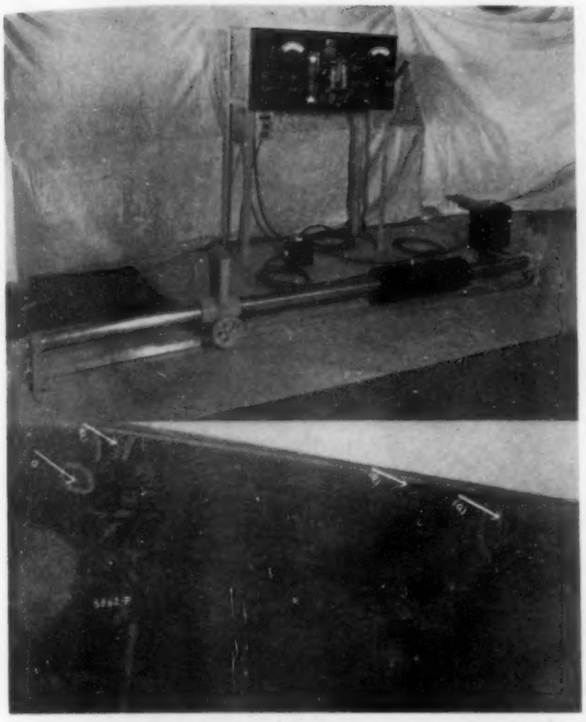


Fig. 13—(Top) Magnetic Testing Apparatus for Large Pieces. (Bottom) Cracks Detected by Magnetic Testing

smooth. It is difficult to detect cracks in the irregular surface of weld metal as deposited.

Spot welding is an automatic process performed by machinery and can be controlled if correct machine settings are established and maintained at all times.

A specification for the inspection of spot welding should require that the pressure and current controls operate so that no current flows until the full pressure is applied at the welding electrodes and the current is out off before the pressure is removed. Partial release and re-application of pressure may be carried out during the welding process. The time in which the current flows should be accurately and positively controlled so that there will be no variation between the timing of individual spots for a single setting of the controls, and there should be a convenient and visible means for measuring the time of current dwell. The correct machine setting can be established by tests on spot welded joints and maintained by tests made periodically during the operation of the machine. A satisfactory test specimen is a lap joint in strips $^5/_8$ inch in width joined by a single spot. This is broken in a tensile machine. The spot is examined for cracks and blow-holes with glass of from 5 to 10 magnification. The tensile strength of the spot for corrosion-resistant (18–8) steel of a minimum strength of 180,000 p.s.i. is indicated on Curve *B*, Fig. 10.

X-ray inspection of spot welds is quite satisfactory.

The general formula which has been found satisfactory for calculating the strength of a similar single spot specimen for aluminum alloys is: Shear strength of single spot joint $= \frac{t \times T.S.}{K}$

t = thickness of material in inches.
$T.S.$ = tensile strength of material in pounds per sq. in.
K = 5 for maximum limit and 7 for minimum defining the zone of acceptable strengths for spots.

A maximum is required in order to eliminate the spots which are cracked due to excessive heat.

These values do not apply when the joint contains more than one spot as the average breaking strength per spot of a multiple spot joint is lower. The single spot joint affords a means of checking the operation of the machine so the spots of minimum breaking strength are obtained.

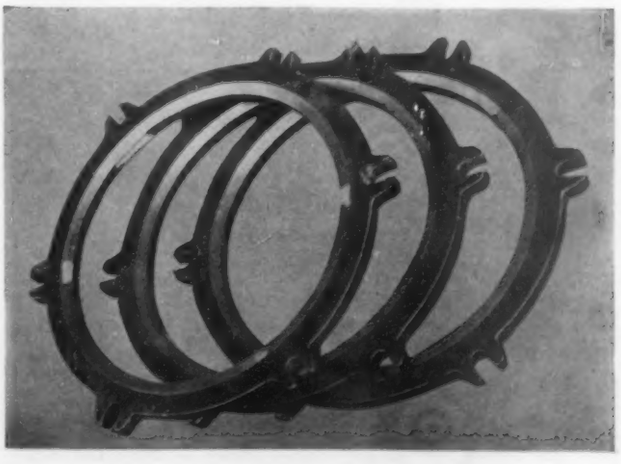
Economical Fabrication

By O. C. JONES*

Complicated Assemblies Achieved by Use of Castings Combined with Flame Shaped Parts

OBVIOUSLY the ideal design for a machine or any type of structure is that in which each component is made of the material best suited to the requirements of the individual part. Welded assembly permits the designer to achieve this ideal because it enables him to utilize to best advantage the specific properties inherent in castings, forgings, flame shaped parts, stampings and other physically different forms.

In the preparation of parts for welded assembly, experience during recent years has indicated that the oxy-acetylene shape-cutting process has exceptional advantages for a large proportion of the work. Almost with-



Flange Rings for Pressure Filters Cut from 1-in. Steel

* Technical Publicity Department, The Linde Air Products Company.

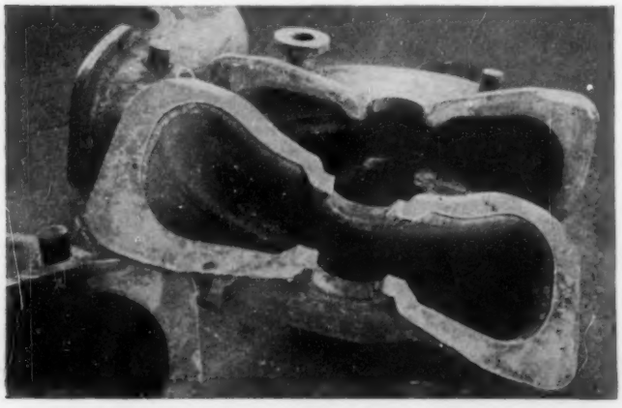
Economical Fabrication of the Bottom Half of the Blower Is Easily Accomplished

out exception, companies which have adopted the process say that they are finding new uses for the process every day. On the other hand, they are equally frank in saying that it cannot replace every type of part production, and they find in certain cases that the best type of assembly is a combination of shape-cut steel plate with forgings, castings or other types of parts.

At one plant an oxyacetylene shape-cutting machine has been in constant use for about six years, fabricating parts for their own use as well as for equipment for outside firms which they are producing on a contract basis. Although, wherever possible, they use shape cutting in preference to other methods, it is interesting to observe that in the manufacture of steam turbine blowers a unique combination of castings with shape-cut parts has made it possible to produce a splendid blower very economically.

The top half of the turbine case consists of a curved steel casting. The flange for this part, 40 × 24 in. in size, is cut from $1^1/_4$-in. steel plate and then welded to the casting. This assembly weighs 162 lb.

Similarly is the bottom half of the turbine case constructed. This 481-lb. assembly consists of a curved casting to the top of which is welded a flange shape-cut from $1^1/_4$-in. steel. This flange matches the one on the top half of the case. In addition, a number of other sections of this assembly are cut on the shape-cutting machine; rings, cross braces and rings for the inlets which are shaped from steel ranging from $^1/_2$ in. to $1^1/_2$ in. in thickness.



Top Half of the Turbine Blower Fabricated from Shape-Cut Steel and Cast Parts

Inlet rings are largely cut from scrap material which is left over from other cutting jobs. These measure overall, $10^5/_8$ in. in diameter. The ring itself is $1^3/_4$ in. wide.

The exhaust part of the turbine blower and the gear case part are similarly constructed. The top part of this weighs 418 lb. and the bottom 213 lb. A number of separate parts are shaped out on the oxyacetylene machine from steel ranging from $^3/_8$ in. to 2 in. in thickness. Other parts are cast. A $^1/_4$-in. tolerance is left on these shape-cut parts for machining on the section where the blower shaft rotates. The rest of the parts described above are cut to a $^1/_{16}$-in. tolerance and used as cut without further finishing.

The flange rings for the pressure filters are cut from 1-in. steel. The inside diameter is 20 in., and the outside diameter 24 in. The diameter to the outside of the lugs is 27 in. These are cut to size and only a very slight amount of machining is done in order to give a perfect seat.

Discussion of Article by T. A. Willson Entitled "Protective Appliances"*

By C. J. HOLSLAG†

IN CONNECTION with the above article I would like to present the other side. No one's eyes have ever been permanently injured by the arc and it is a healthy occupation. All arc welders become more and more healthy looking.

I have never seen any welder using respirator or gas mask of any kind. A slight sensible precaution like staying on the windward side of the fumes when welding dirty steel or on non-ferrous metal is all that is necessary. Even the most violent cutting of bronze can be made safe with an ordinary desk fan running at a slow speed directing the fumes away from the operator.

* Published in July issue of JOURNAL.
† Electric Arc Cutting & Welding Co.

ANNUAL MEETING

Members of the AMERICAN WELDING SOCIETY are reminded that the annual fall meeting of the Society will be held in Cleveland, Oct. 19th–23rd in connection with the Metal Congress and Exposition.

Plan to attend!

Some of the best papers to be presented in recent years will be given at the various technical sessions. A complete program was published in the July and August issues of the JOURNAL.

Some Diversified Recent Welding Applications

By A. F. DAVIS†

New Truck Quiets Operation of Surface Cars

A NEW type of arc welded truck for streamlined surface cars, result of a great deal of research by electric railways of the United States, and said to be practically silent in operation, was recently delivered to the Capitol Transit Company of Washington, D. C., by the St. Louis Car Company, St. Louis, Mo.

The new truck (see Fig. 1), features a frame which is fabricated entirely by arc welding. By using welded construction in place of former methods, employing a combination of casting and riveting, the builder reduced weight by approximately 20 per cent. In addition to saving weight, the builder reports arc welding provides more flexible construction to compensate for irregularities in track surfaces. A further advantage of the new type of construction is that it eliminates the casting of complicated shapes, and permits small changes in design or the use of variable equipment without making the pattern changes which would be required for cast construction.

† Vice-President, The Lincoln Electric Company.

Fig. 1—Destined to Provide a New Quietness of Operation, This New Truck, Built for Streamlined Surface Cars, Has an All Arc Welded Frame

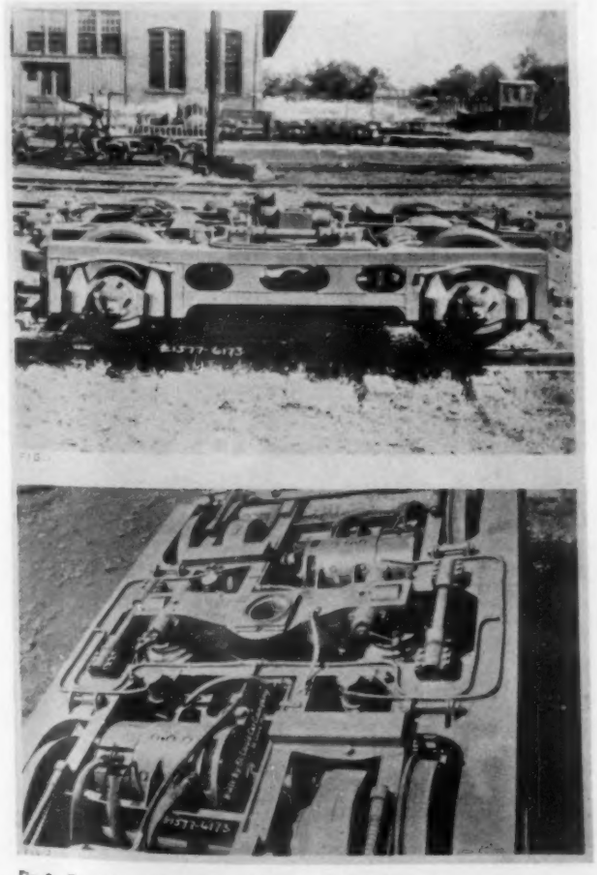


Fig. 2—Top View of Streamlined Surface Car Truck Showing Arc Welded Frame

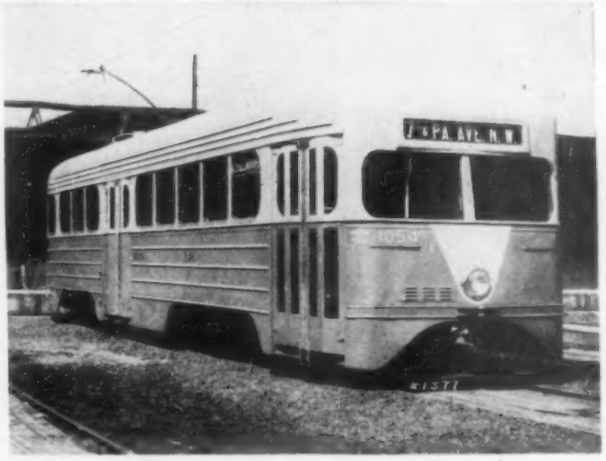


Fig. 3—Completed Streamlined Car

Built by arc welding, the truck frame is merely standard channels, angles, plate and bar stock cut to proper sizes, assembled and fused together into a single homogeneous unit. (See Fig. 2.)

Twelve-pound ship channels are used for side frame and pedestals. Transoms are 15.3-pound channels. Angles 4 x 3 x $^3/_8$ inch are used for end frames, corners and one gear support. Motor support frames and inside wheel piece are 3 x 3 x $^3/_8$-inch angles. Steel plate $^3/_8$-inch thick is used for motor support, frame gussets and brake hangar plate, while a second gear support is $^1/_4$-inch plate. The pedestal arch stiffener is 1 x $^1/_2$-inch bar stock.

In construction, the main frame members were assembled in a jig and tack welded together. Following tack welding, all parts were placed and welded.

The new truck, tested in actual service, provides a new smoothness of operation. It is completely insulated with rubber. The springs have rubber spacers and disks which prevent transmission of sound from wheels through the trucks to the car. Practically the only sound heard, as the car travels, is the contact between wheels and rails (Fig. 3).

Outlet Fitting

This horn-shaped structure (Figs. 4 and 5), spreading out from 8 inches diameter at the bottom to 8 feet at the top, was once a single flat piece of $^3/_{16}$-inch ingot iron. The structure is still a single piece of metal—only the shape is different. It was made by cutting out 26 pieces,

Fig. 4

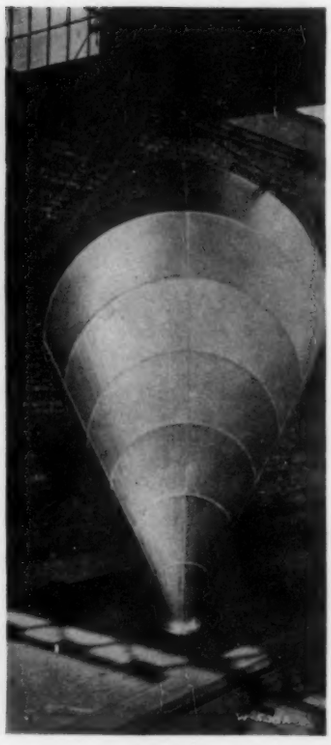


Fig. 5

then fusing them all together into one integral unit by the shielded arc process of electric welding. Now the structure is an outlet fitting for the cone of a clarifying tank used in sewage disposal work. It was fabricated by the Farrel Manufacturing Company, Joliet, Illinois.

Stainless Steel Lining

Thirty thousand holes but not a single leak!

Shown here is a portion of a stainless steel lining welded into a cracking plant dephlegmator. To apply the lining, holes $^{9}/_{32}$ inch diameter were punched $1^{1}/_{2}$ inches apart in $^{1}/_{16}$-inch 18–8 stainless steel sheet. These holes—totaling 30,000!—were then welded up inside the dephlegmator with a special 18–8 stainless steel arc welding electrode. The lining has been in service seven months without a single leak. The welding was done by La Consolidada, S. A., Mexico, D. F. (Fig. 6).

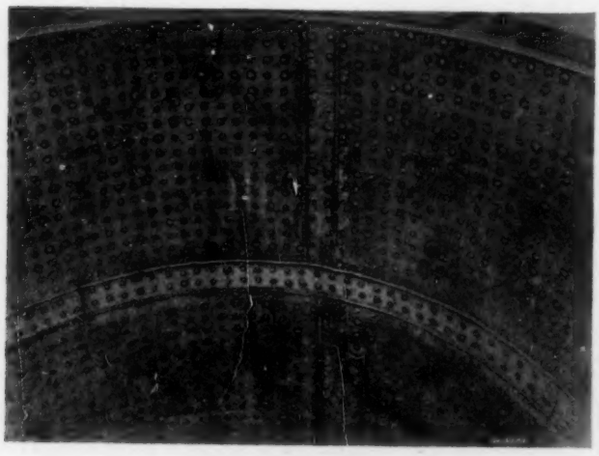


Fig. 6—Stainless Steel Lining

San Francisco Bridge

High above waters now spanned by the San Francisco-Oakland Bay Bridge—world's largest bridge project—flashes the electric arc, fusing steel to steel in placing the floor beams on the lower deck of the suspension span. Previously, this miracle of modern structural processes speeded sinking of the gigantic pier caissons of the bridge—one of them 197 feet long and 92 feet wide.

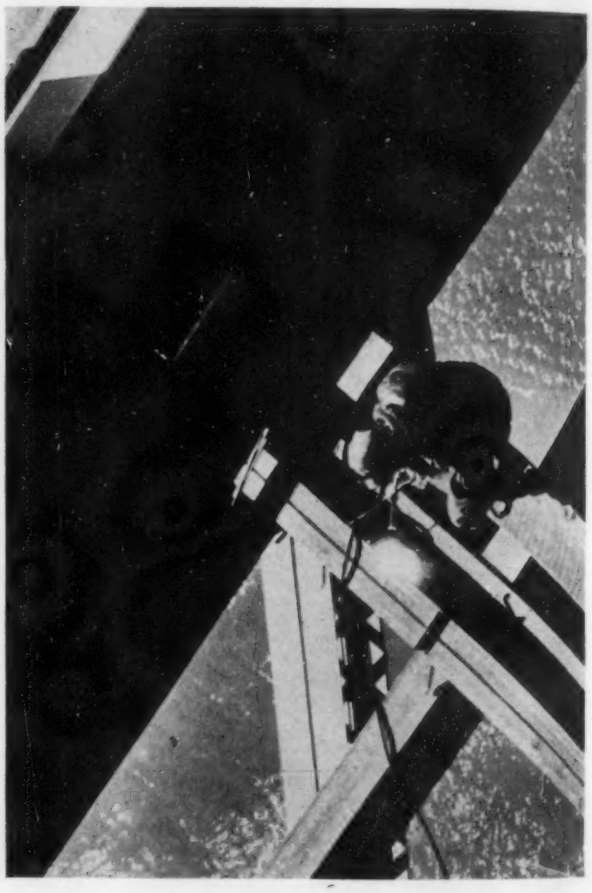


Fig. 7—Welding on San Francisco Bridge

Bascule Railway Bridge

Main line high speed traffic on the Florida East Coast Railway now speeds across a bridge structure which is said to be the first of its type in existence. It is a 60-foot bascule span across the Lexahatchee River near Jupiter, Florida, fabricated and erected entirely by arc welding. This construction saved $42^{1}/_{2}$ tons weight in the span and 100 tons in the counterweights. Traffic was interrupted only $6^{1}/_{2}$ hours during erection.

This work has been carried out under the general direction of L. C. Frohman, Chief Engineer, and T. H. Gardner, Structural Engineer for the Florida East Coast Railway.

Figure 8 shows the Miamian, crack New York-Miami flyer, speeding across the bridge at 50 miles an hour clip, and (Fig. 9) the span raised.

30-Year Old Viaduct Is Rejuvenated

The Intercity viaduct, connecting Kansas City, Kansas, and Kansas City, Missouri, has been a traffic bottleneck for years. This structure, $1^{7}/_{8}$ miles long, built in 1905–1906, was only 36 feet wide, entirely inadequate

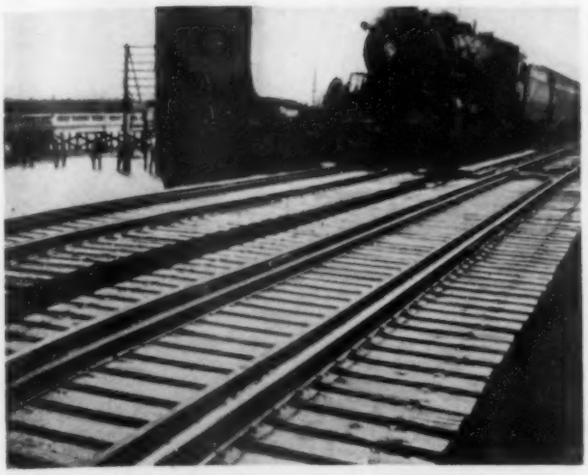


Fig. 8—Train Crossing Welded Bascule Bridge

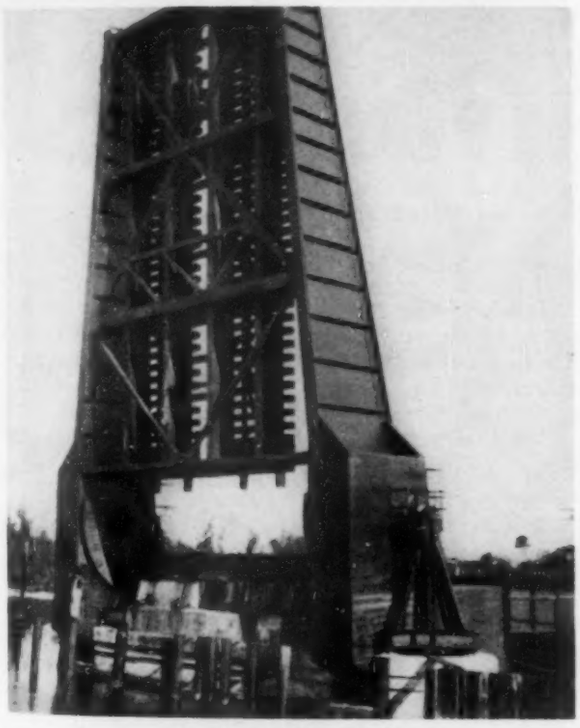


Fig. 9—Welded Span Raised

Fig. 10—Intercity Viaduct between Kansas City, Kansas, and Kansas City, Missouri, Being Widened and Reinforced by Shielded Arc Welding

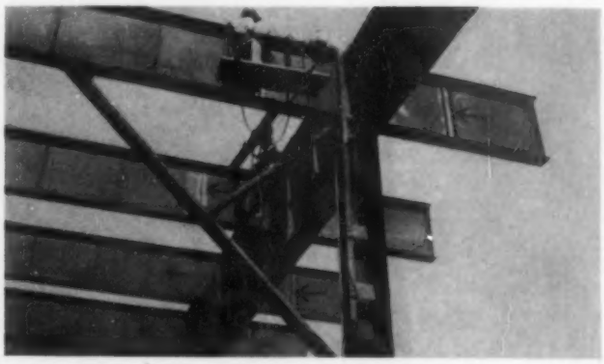


Fig. 11—Reinforcing the Floor Beams by Arc Welding Stiffeners to the Beams

for present-day traffic. But things are going to be different this fall. The bridge (see Fig. 10) is being widened to 46 feet. The project is being carried out jointly by the state highway departments of Kansas and Missouri.

Considerable reinforcing is being done to the bridge to enable it to carry the increased load. Stiffeners—540 of them—are being welded to the main load-carrying members. (See Fig. 11.) To further strengthen the structure, the heavy floor beams, which were found to be severely weakened by corrosion, are being reinforced by welding steel plate to them. Support for the 4-foot sidewalks on the north side of the bridge is being provided by a 12-inch stringer (see Fig. 12), arc welded to clips attached to the beams. This construction is shown in Fig. 13.

Approximately 16,000 feet of guard rail is being added to the bridge. This rail, requiring approximately 350 tons of steel, is being entirely shop fabricated by arc welding by the Builders Steel Company, North Kansas City, Mo., who are also supplying a large part of the

Fig. 12—Twelve-Inch Channel (Right) Installed for Sidewalk Stringer on Intercity Viaduct

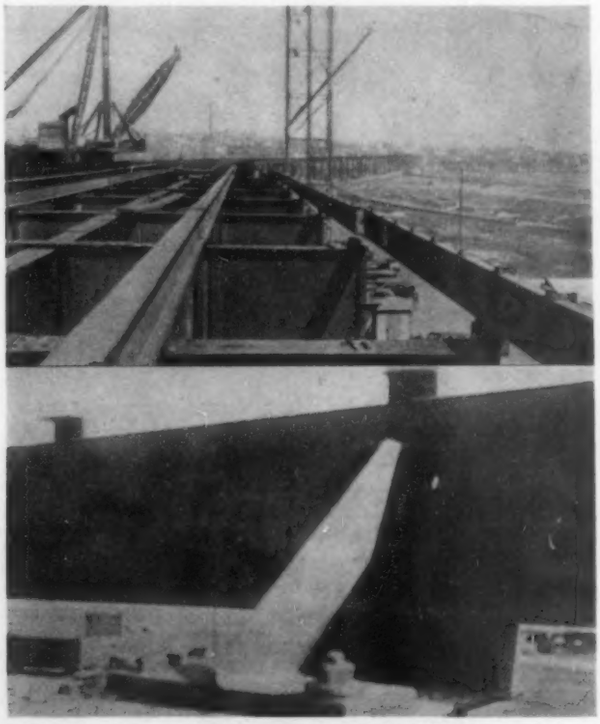


Fig. 13—Brace for Sidewalk Stringer Welded to Clip Attached to Beam and Stringer

Fig. 14—Fabricating a 15-Foot 3-Inch Section of Guard Rail. This Jig and Arc Welding Enable Two Welders and One Helper to Fabricate 20 Such Sections per Day

steel on the project. The rail is built up in sections, averaging 15 feet 3 inches in length. The fabrication of a section by arc welding is shown in Fig. 14.

As shown in Fig. 14, a special jig is used to hold the channels and bars securely in place for welding. This method eliminates the need of tack welding. By using this jig, two arc welding operators and one helper who fits the parts together, complete 20 sections of rail a day.

The welding on the Intercity Viaduct is required to meet specifications of the Kansas and Missouri state highway departments which are the same as those of the AMERICAN WELDING SOCIETY. Arc welding operators were qualified according to Welding Society rules.

Contract for remodeling the bridge was awarded to M. E. Gillioz, Monet, Missouri, who sublet the erection of the steel to Stroebel Construction Company of Chicago, Illinois. The Stroebel Construction Company is doing the welding.

Reinforced Concrete Pipe

Not a wierd species of animal tampering with a monster's cage in a zoo but two arc welding operators at the Riverside, California, plant of American Concrete and Steel Pipe Company joining steel to steel by the electric arc in fabricating the reinforcement for 16-foot diameter concrete pipe being used in constructing the $283,000,000 Colorado River aqueduct (see Fig. 15). This gigantic project will bring a billion gallons of water per day from the Colorado River, 252 miles to cities in the Metropolitan Water District of Southern California.

Fig. 15

Vessels for Low Temperatures*

By R. K. HOPKINS†

Introduction

UP UNTIL the year 1931, practically all pressure vessels used in low temperature service were of relatively small size such as coolers, evaporators, etc., usually made up of standard pipe and fittings. Most of these vessels were made of plain carbon steel, but in some few cases alloy steel was used.

It is only within the past four or five years that large sized pressure vessels have been put into service at sub-zero temperatures. These vessels are used primarily in the oil dewaxing plants where propane or some other suitable liquid is used as a refrigerant. These plants not only operate at low temperatures, usually at from $-40°$ to $-75°$ F., but at high pressures as well.

Some chemical processes also require the use of large pressure vessels at sub-zero temperatures, one such plant having been built recently which operates at a temperature of $-112°$ F. Since very large quantities of the refrigerant are carried in the system, and since the vapor pressure of the refrigerant is naturally low, the potential danger incident to failure of any part of the plant, particularly the large pressure vessels, is great.

Because of this fact, extreme care should be exercised in choosing materials for different parts of the plant, and in specifying methods of fabrication and heat treatment. It should be kept in mind at all times that the specifications for the metal, the fabrication procedure and heat treatment must be applied to the full sized vessel and

* A contribution for the proposed Welding Handbook of the AMERICAN WELDING SOCIETY. Constructive criticism is invited.

† Director Metallurgical Research and Development, The M. W. Kellogg Company.

must not be based entirely on laboratory tests made on small specimens.

Physical Properties of Metals at Sub-Zero Temperatures

It is an established fact that the tensile strength and yield point of almost every metal increases as the temperature is lowered. This increase in tensile strength is usually accompanied by a decrease in ductility as determined by the elongation of a tensile bar. The decrease in ductility, however, is not usually so marked as the increase in tensile properties.

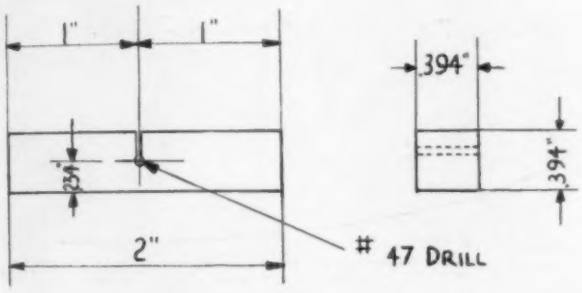


Fig. 1

That property of a metal which is likely to suffer most due to decrease in temperature is its resistance to shock.

Some metals, such as plain carbon rimmed steels which have a relatively high notched bar impact resistance at room and elevated temperatures, lose practically all of this property when the temperature is reduced only a few degrees below zero, and in some cases at even 20° F. above zero, while the notched bar shock resistance of some other metals such as copper and some solid solution alloys, is almost unchanged by exposure to sub-zero temperatures.

Although the tensile strength of a metal increases as its temperature decreases, this fact should not be taken as an assurance that such a metal would be safer to use at low temperature than at some higher temperature. Its impact or shock resistance at the operating temperature should be determined, and given serious consideration.

Unfortunately, no method has yet been developed to enable the designing engineer to incorporate in design the values determined for shock resistance by the usual impact testing methods. Even so, impact properties should not be disregarded. The impact test at least enables one to obtain qualitative results so that the shock resistance of untried metals may be compared with those of metals which have proved themselves in service.

Although impact data cannot be incorporated in design, some minimum value must be decided upon so that specifications may be written to cover the material. This value can only be accurately determined from actual service conditions where a metal having some definite impact value (as previously determined by laboratory tests) has or has not been satisfactory in service. This procedure is not usually possible and it therefore becomes necessary to assume some minimum acceptable value.

Based on the Charpy keyhole notch bar, a value of 10 ft.-lb. has been used without trouble in some oil dewaxing plants.

Physical Test Procedure

In determining the physical properties of any material, it is important that the test specimens be taken from material that is as near the form in which it is to be ultimately used as possible. This is particularly true in the case of large plates where the manufacturing difficulties encountered in making the steel and rolling the plates usually have a very decided effect on the physical properties of the steel in its final form. It is strongly recommended that data not be relied upon too strongly when collected from test specimens produced from small laboratory furnace ingots, or when taken from types of products other than those contemplated for use.

In testing plate materials, the specimens should not only be taken from one section of the full sized plate, but should be taken from various parts of the full sized plate so that the effect of all contributing factors, such as segregation, direction of rolling, etc., on the physical properties can be fully determined. Any heat treatment which may be prescribed should be carried out on as large a sample of the full plate thickness as possible. Heat treatments carried out on small specimens are liable to give misleading results on account of the widely differing rates of cooling and heating obtainable on small samples from those obtainable on full sized plates or cylindrical sections.

Tensile Testing

The tensile properties of a metal at low temperatures can be determined rather simply by either having the room in which the testing machine is located cooled to the testing temperature, or the test specimen itself cooled by some suitable form of container through which the cooling medium is pumped before and, if necessary, during the test. It is possible to precool the specimen along with the jaws of the machine before the test is run, provided too much time is not lost between the time the specimen is removed from the cooling medium and the time the test is actually run. In this case it is necessary to determine by actual test the rate of rise in temperature and then correct for this by cooling the specimen to a temperature the required number of degrees below the desired temperature so that the actual test will begin at the proper temperature. It is recommended that where possible, the test be run under either one of the first two conditions mentioned.

Impact Testing

Although several methods have been developed for determining the impact properties of metals, the two used most widely in America are the Charpy and Izod methods. The Izod method, on account of the type of notch used, is probably more selective than the Charpy method, particularly when the keyhole type of Charpy bar is used, but because of this, the data collected are somewhat more scattered and for this reason it is felt that the Charpy test using a keyhole notch bar gives the most consistent and, therefore, the most reliable information. The details of the Charpy keyhole notch bar are given in Fig. 1.

In conducting impact tests at low temperatures, the specimens are usually placed in an insulated vessel containing acetone or some other suitable liquid. The temperature of the liquid and the specimens may be lowered by the addition of dry ice down to a point approximately 3° F. below the required testing temperature. It has been found that if the test specimen is broken in no more than 8 seconds after removal from the bath that the temperature will not have risen more than 3° F. The template used for centering the specimen in the machine should be kept cold so that it will not contribute to the rise in temperature of the specimen.

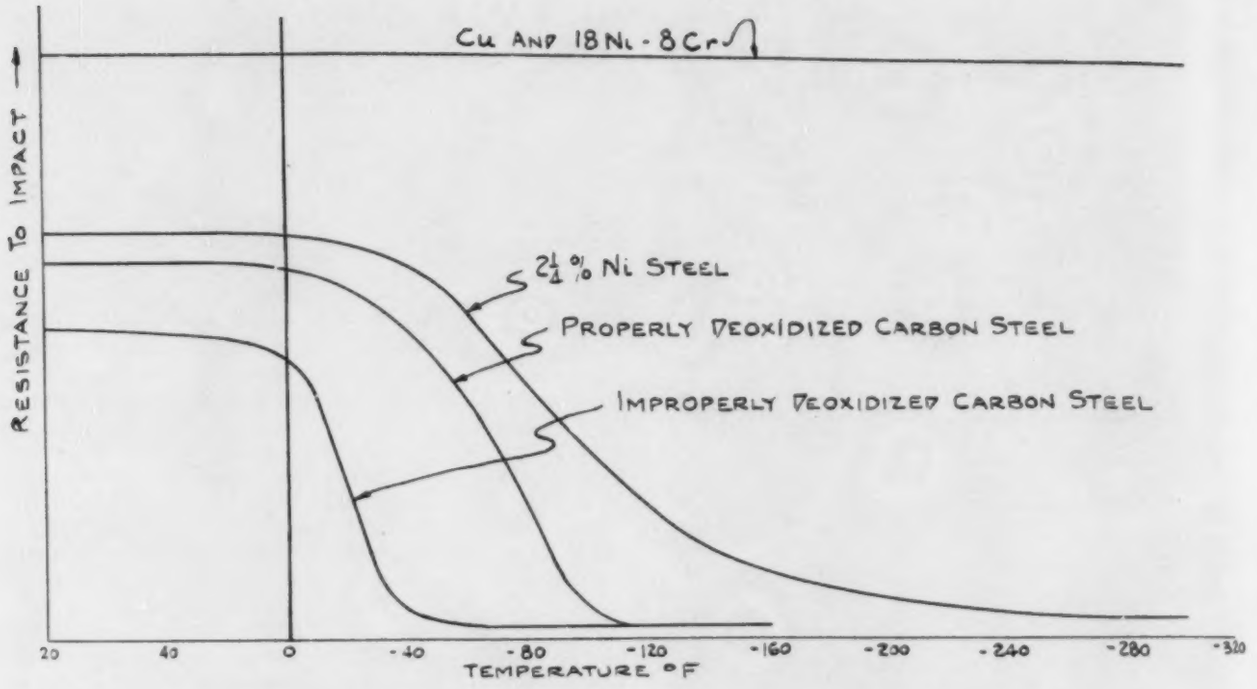


Fig. 2

Full Sized Tests

Since the results of Charpy or Izod tests cannot be correlated in design, it is strongly recommended that where possible, hammer tests under pressure at operating temperature be conducted on full sized vessels, or certainly on models of the proposed vessels. This type of test is usually rather difficult and expensive to run, but it is felt that where the safety of a unit is at stake such a test is justified.

Weldability

Since practically all vessels used for high pressure service are now welded, the weldability of the material proposed must be considered and thoroughly investigated. Actual full thickness samples of the proposed materials should be welded under shop conditions and given the exact heat treatment which the vessels in normal production would receive. The physical properties of the weld metal and adjacent zone should be accurately determined for the full range of operating temperatures. All test welds, as well as production welds, should be thoroughly examined by the X-ray.

Materials

In addition to choosing a material which has both weldability and acceptable physical properties at sub-zero temperature, the matter of cost must also be considered. As stated above, the solid solution metals usually have good impact resistance at sub-zero temperatures. Copper is one such material but, unfortunately, its tensile strength is usually too low to make its use economical for large pressure vessels. Austenitic stainless steel has good impact properties, tensile strength and weldability, but the cost is high.

A medium-carbon low-alloy steel containing approximately 2¼% nickel has proved itself to be very satisfactory for temperatures down as low as −75° F. A great deal of this material has been used in the past few years for the construction of low temperature pressure vessels. Although this steel is a great deal more economical than the austenitic stainless steels, it is still quite high in price as compared with regular carbon steels. But plain carbon steels, made in the ordinary way, show extremely erratic and generally low impact resistance at low temperatures. Recent tests, however, indicate that if carbon steels are made under proper deoxidizing practice, their low temperature impact resistance is greatly improved. Figure 2 shows in a general way the relative shock resistance of these steels as the temperature is lowered. The property of high impact resistance at low temperatures seems to be related to the deoxidizing practice which in turn controls the inherent grain size of the material as determined by the McQuaid-Ehn grain size test. It has been proved that the finer the grain of a metal the higher the low temperature impact resistance, but this does not mean that any material can be made good by grain refinement alone. In pearlitic steels it seems necessary that the inherent grain size as produced by the deoxidization practice be small in order to obtain good low temperature impact resistance. Increasing carbon content tends to decrease the low temperature impact resistance. It is recommended that until further work is done on the straight carbon steels, that some one of the alloy steels which has proved itself satisfactory in low temperature service be used.

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Welding Bottom of Gas Holder

By D. P. CONNERY†

THIS immense plate of sheet steel, 220 feet in diameter and weighing approximately 300 tons, was lowered into place on its foundation on July 16th at the Ford Motor Company's Rouge plant. It will serve as the bottom of a 10,000,000 cubic foot gas holder, and is the first welded bottom plate of this size ever built. The circular plate is made of hundreds of small plates electrically welded together. Heretofore plates of this kind have been joined by rivets. During the welding process the plates were held up three feet above the foundation by 160 screw-jacks and by balks of wood around the rim. When the 300-ton gas-tight plate was finished, a crew of men employed by Stacey Bros. Gas Construction Company of Cincinnati, which has the contract for the gas holder, lowered the plate inch by inch by turning the jacks down. The plate rests on a carpet of sand above the mat of concrete, which is supported by piles running down to hardpan. The gas holder is scheduled to be completed late this year and will tower 350 feet in the air, as high as a 35-story building and a little above the great stacks on the Rouge plant power-house, largest high-pressure steam power plant in the world.

† N. N. Ayer & Son, Incorporated.

Bronze-Welded Anchor Clips*

Tests to Determine the Shearing Strength of Clips Bronze-Welded to Cast-Iron Pipe

THE Testing Laboratories of the Department of Civil Engineering of a prominent eastern university recently carried out tests to determine the shearing strength of steel anchor clips bronze-welded to cast-iron pipe. The work was done for the Sectional Committee on Specifications for Cast-Iron Pipe organized under the procedure of the American Standards Association and sponsored by the American Gas Association, American Society for Testing Materials, American Water Works Association and New England Water Works Association. The results of these tests have been published by the Sectional Committee in a bulletin which is one of six of a series describing various experimental studies on cast-iron pipe and fittings. The results are of particular interest to gas and water companies.

The Problem

When cast-iron pipe with bell-and-spigot joints is laid, and it is known in advance that the strength of the joining material is insufficient to keep the pipes from slipping at the joints more than the permissible amount, due to the high pressure in the pipe line, bad ground outside or other causes, tie rods carried across the joints are often used. Ordinarily for such joints, lugs are cast as integral parts of the pipes. These are located near the spigot end. These lugs are usually slotted for bolts and give a bearing for nuts on the bolts.

When this type of connection is desired or is being installed, it is necessary to line up the pipe sections so that the bolts, which are positioned across the joint longitudinally with the axis of the pipe, will be correctly aligned. Thus little leeway in the way of rotation of the pipe and fittings may be allowed. In order to allow greater leeway, use is sometimes made of clamps bolted around the spigot end of the pipe, or of clamps on each pipe end. These clamps depend for their holding power on friction on the pipe. These methods have certain disadvantages which are inherent in their design.

Another type of design was developed which works much better. Cast-iron blocks bear against a raised rectangular shoulder cast integral with the spigot end of the pipe and lugs are cast on the bell end. At each end of the joint, back of the blocks, is a set of steel plate links. Bolts pass through holes in the links where they meet. This type of harness is recommended by the Sectional Committee as preferable to clamps, and where it is known in advance that it is to be used, the pipes may be ordered with the necessary collars cast thereon.

Occasionally emergencies arise, however, and it may be found necessary or desirable to use this link harness at a joint where the cast shoulders have not been provided. In such case a pair of short steel clips, curved to the circumference of the pipe, may be bronze-welded to the spigot end of the pipe on opposite sides and in a proper position for holding the harness. It was the desire of the Sectional Committee to get a good idea of the holding strength of such clips bronze-welded to the cast-iron pipe, and at the same time some idea of the cost.

Tests were therefore devised for determining these facts. Pieces of cast-iron pipe were taken to a commercial welding shop, where the steel clips required for the tests were made. Half of the clips were welded on at this shop in order to give an indication of what results could be obtained in any location where a commercial welding shop could be found. The other half of the welding was then done at the shops of the manufacturer of welding gases in order to show results that might be obtained by experts in bronze-welding.

The Test-Pieces

For test specimens three 18-in. lengths of 12-in. Class "B" cast-iron pipe, $^5/_8$ in. thick were obtained, to each of which two pairs of clips were bronze-welded. The pipe was lined with cement $^3/_{16}$ in. thick to which a bitumen coat had been applied.

Each clip consisted of a 3-in. by 8-in. by $^1/_2$-in. steel plate curved to fit the outside of the pipe. It was bronze-welded to the outside of the pipe with the 8-in. edges placed circumferentially. There were two pairs of clips welded to each length of pipe. One pair, with the plates diametrically opposite, was located at about the middle of the pipe; the other pair, at 90 deg. to the first pair, was located about 4 in. from the end of the pipe. The clip plates were welded to the pipe with $^1/_2$-in. fillet type welds along the two 3-in. edges, and along one 8-in. edge, leaving the other 8-in. edge free from welding except for a tack-weld at each corner. In every case the test loads were applied to the unwelded edges of the plate.

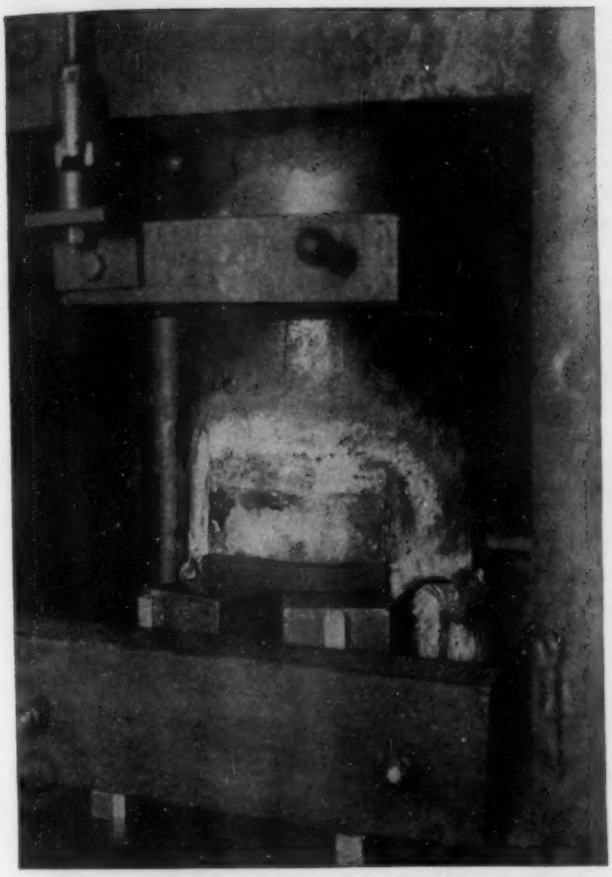
The Test Method

The load in each test was applied simultaneously to the unwelded edges of two diametrically opposite clip plates in a direction parallel to the axis of the pipe. The pipes were placed vertically in a 400,000 lb. tensile testing machine, the specimens supported on suitable steel blocking, and the load applied actually to the top of a specimen. The loading of each pair of clips was continued until one or both clips were broken off.

The Test Results

The average direct load applied to the specimens welded by the contract welding shop when failure occurred was 240,500 lb. The average load for the other specimens welded by the bronze-welding expert was 303,300 lb. The fracture was not through the throat of the weld, but rather by shear through the bronze parallel to and within a few thousandths of an inch of the surface of the cast iron, or by breaking out the cast iron at the contact surface. It was observed that the fractures always started at the bearing edge of the side welds, progressing toward the 8-in. welded edge. Following the fracture of the side welds the clip rotated outward until the long welded edge also fractured. The method of

* Reprinted from the August issue of "Oxy-Acetylene Tips."



A Test-Piece in the Testing Machine Showing Method of Support and Loading

load application produced combined shear and outward bending stresses in the welds.

The greater loads required to break off the clips welded by the bronze-welding expert may have been due in part to the greater area of contact of weld metal with the cast iron, and also because of the larger tack-welds used at the ends of the bearing edge which were effective in resisting the outward rotation of the clip. Approximate areas indicate that shearing stresses of at least 46,000 lb. per sq. in. were developed in the total throat area of the welds, and stresses of 20,000 to 25,000 lb. per sq. in. of fusion contact.

Conclusions

In the published report on this work, it is interesting to note certain conclusions prepared by the designing engineer of the Board of Water Supply (also a member of the Sectional Committee) who was a witness of the test. He states that, "With a 12-in. pipe tied with two bolts instead of the customary four, according to the lowest test (bronze-welded steel clips), a pair of clips would have sustained a hydrostatic pressure on a circle of diameter equal to that of the socket of a Class "D" bell of 1430 lb. per sq. in., and the clips would have been stronger than $1^{3}/_{4}$-in. bolts stressed 60,000 lb. per sq. in. at the root of the thread." He goes on to point out that "In the test, the part of the pipe above the clips was in axial compression, whereas in actual service it would be in tension. Stated in another way, in the tests both the clip and the part of the pipe to which it was welded were in compression parallel to the axis of the pipe, whereas in actual service the clip would be in compression but the underlying part of the pipe in axial tension, resulting in greater shearing strain between clips and pipe for a given load. Failure is to be expected, therefore, at a somewhat smaller load per clip in actual service than in these tests."

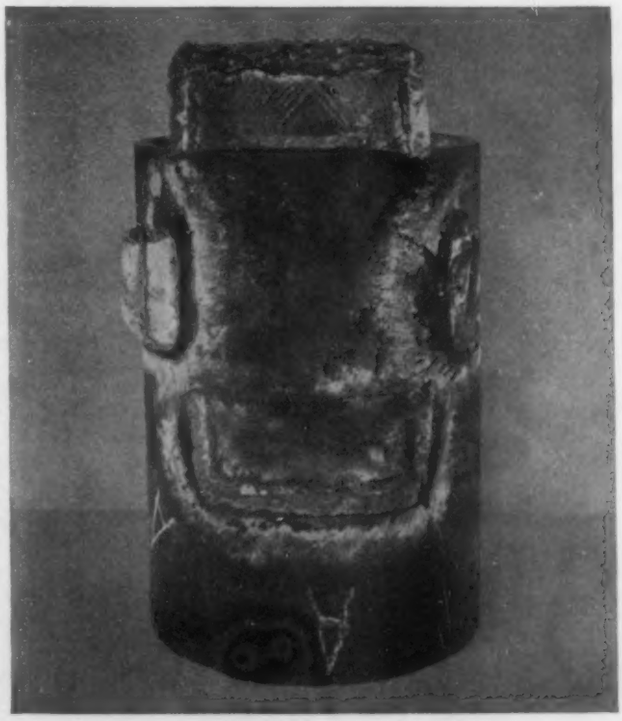
He states further that "Circumferential expansion of the pipe due to internal water pressure, absent in these tests, would cause another shearing strain, this time tangential, between clip and pipe. This would further tend to reduce the load-capacity of the welded clips in service, compared with these tests.

"Notwithstanding the probably smaller strength in service than in these tests, the 'Equivalent Hydrostatic Pressure' indicated in the fifth paragraph, which includes no allowance for the shearing strength of the lead or other joining material, is so much in excess of pressures used, and, for the 12-in. size, so much greater than the strength of ordinary cast-iron pipe, that there appears to be no doubt that clips of the dimensions tested would be adequate for all except possibly the largest sizes of pipe. Clips wider along the pipe, or both wider and longer circumferentially, should have greater load-carrying capacity than the clips tested, particularly with liberal welds on the ends of the bearing edge, and should probably be used for the largest pipes, particularly at the higher pressures.

"This design is intended merely as an emergency device when specially made pipe is not available. The cost is, perhaps, not important. In this particular set-up six clips fitted to the pipe cost $9.00 and six welds $27.00, making the total $6.00 per clip."

This is undoubtedly a high cost due to the fact that these were special test specimens.

In connection with the effect of the use of these clips on the cement lining, the report goes on to say that "There is nothing to indicate, however, that this mortar would ever fall off and, though undoubtedly damaged, it seems reasonable to assume that, if repainted, it would have a long, useful life."



Steel Lug Sheared from Pipe Shows the Shearing Strength of Bronze Bond

WELDING SOCIETY ACTIVITIES AND RELATED EVENTS

"Clinics" to Show Latest Welding Practice for Non-Ferrous Alloys

Latest developments in welding practice for non-ferrous alloys will be demonstrated at two "clinics" to be held in Cleveland, Ohio, and Buffalo, N. Y., during September. Included will be practical examples and demonstrations of the latest methods of electric and oxyacetylene welding and brazing on Monel, aluminum, nickel, copper, brass, bronze, Inconel and nickel-clad steel.

The "clinic" at Cleveland will be conducted by welding engineers of The International Nickel Company, The Aluminum Company of America and The Revere Copper and Brass Company. It will be held in the warehouse of Williams and Company, Inc., 1748–56 East 22nd Street, on September 18th and 19th.

At Buffalo, the clinic will be held on September 25th and 26th in the warehouse of Whitehead Metal Products Company of New York, Inc., 254 Court Street. It will be under the auspices of The International Nickel Company, The Aluminum Company of America and The American Brass Company.

Somewhat similar clinics have been planned for Montreal and Toronto in October.

Year Book Omission

We announce with considerable regret the inadvertent omission of the name of Mr. A. R. Wilson, Engineer of Bridges & Buildings, The Pennsylvania Railroad, Broad Street Station, Philadelphia, Pa., from the alphabetical and geographical membership lists. Mr. Wilson is an Associate Member of the Society.

International Acetylene Association to Meet in St. Louis

The International Acetylene Association will hold its Thirty-Seventh Annual Convention in St. Louis at the Jefferson Hotel, November 18th, 19th and 20th. This will be the first time that the convention has been held in St. Louis.

Technical sessions will be held each afternoon and on two evenings. The oxyacetylene process for welding and cutting metals will be featured at these sessions. As the result of a year of unusual developments, a series of vitally interesting subjects will be discussed by speakers who are key men in their fields.

Wednesday evening, November 18th, is to be devoted to a forum on welding and cutting. The evening session Thursday, November 19th, is intended to comprise a series of popular round-table discussions on oxyacetylene welding and cutting practices.

A cordial invitation to attend this Convention is extended to every one interested in the practical applications of the oxyacetylene process.

German Meeting

The German Chemical Society cooperating with the German Acetylene Society and the Society for Gas Welding, at their summer meeting, July 5th–11th, at Munich, devoted an entire session to gas welding. The following papers were presented.

1. Gas Welding Pure Aluminum for Chemical Apparatus, by Dr. Zimmermann.
2. Welding Hydronalium and Elektron, by Mr. de Ridder.
3. Hardening Unalloyed Cast Iron with the Oxyacetylene Flame, by Mr. K. Bossert.
4. Electrostatic Charges Developed by Gases in Motion, by Dr. Rimarski.
5. The Velocity of Gasification of Carbide as a Function of Structure and of Type of Gasification, by Mr. Sauerbrei.
6. Practical Examples of Welding in the Construction of Chemical Apparatus, by Mr. A. Rupp.
7. Causes of Accidents and Their Prevention in the Use of Acetylene Generators and Cylinders, by Dr. H. Friedrich.

Results of the Second International Congress for Developing the Uses of Calcium Carbide and Acetylene

The French Manufacturers of Calcium Carbide and the International Syndicate of Calcium Carbide jointly organized in 1935 the *Second International Congress for Developing the Uses of Calcium Carbide and Acetylene.*

This Congress, open to engineers of all countries, was intended to summarize all research into new uses, or into the development of well-known uses of calcium carbide and acetylene.

Each speaker presented a paper dealing very completely with the invention, new idea or new development that he was responsible for, and stated its bearing on the applications of calcium carbide or acetylene.

The papers were due May 1, 1935; at the latest March 1, 1936.

Fifteen speakers presented papers: France 6, Germany 3, Belgium 2, Switzerland 2, Italy 1, Sweden 1.

The papers were examined by a Technical Jury who reported their recommendations to the Congress Committee, who, according to rules, made the final selections.

The results should have been announced June 30, 1936, but unfortunately the results were not available until July 17th, at the end of the meeting of the Committee.

A sum of 50,000 francs (French) was put at the disposal of the Committee by the organizers.

The Committee, after considering the report of the Technical Jury, awarded the following prizes:

First Prize: 15,000 francs, to Mr. R. Meslier, for his paper, "Riveting and Arc Welding Economically Displaced by the New Methods of Oxyacetylene Welding.—Vertical Welding Using Two Torches, One on Each Side of the Weld."

Second Prize: 8000 francs, to Mr. C. F. Keel, for his paper, "Activated Gas Welding."

Third Prize: 5000 francs, to Mr. Otto Joseph Schleimer and Dr. Ing. Karl Roesch, for their paper, "A New Weldable Cast Iron and Its Use."

Fourth Prize: 3000 francs, to Mr. Paul Welter, for his paper, "Use of Acetylene or Calcium Carbide in the Rubber Industry."

Acting on the suggestion of the Technical Jury, the Committee decided to award prizes to the authors of the most interesting, most authoritative and best presented papers. They therefore awarded 1500 francs to:

1. The authors of the four prize papers: R. Meslier, C. F. Keel, Schleimer and Roesch and P. Welter.

2. To the following: Mr. Zuliani, for his paper, "Industrial Heating by Acetylene." Mr. C. F. Keel, for his paper, "New Ideas on Materials for Ship Construction.—Gas Welded Pontoon." Mr. S. Aug. Eskilson, for each of two papers—the first, "Shrinkage and Shrinkage Stresses in Fusion Welding by Torch and by Arc"; the second, "Apparatus for the Automatic Welding of Thick Plates."

A prize of 1000 francs was awarded to the following authors: Mr. Sanfourche, for his paper, "Application of Calcium Carbide in the Manufacture of Compressed Powders Intended to Be Dissolved in Agricultural Use." Mr. H. Lacour, for his paper, "Air-Acetylene Cutting Torch." Mr. H. Demay, for his paper, "Presentation of the Acetylene Motor Requiring No

Carburetor, the Universal Generator, and the Universal Distribution for the Equipment of the Acetylene Motor." Mr. Marc Aubert, for his paper, "The Acetylene Motor Working on the Vaporizer Principle for Motive Power." Mr. A. Marchal, for his paper, "Equipment Required for the Acetylene Motor."

The prizes distributed come to a total of 48,000 francs (French). The remaining 2000 francs was left to the organizers for use as they saw fit.

As can be seen from the titles of the prize papers, the papers presented comprehend almost all fields of application of calcium carbide and acetylene: motive power, heating, agriculture, chemicals and, particularly, gas welding, which is at present the principal outlet of calcium carbide and progress in which may lead to even greater increase in consumption.

The most interesting papers will be published with the consent of their authors.

Effective Organization*

By E. B. MEYER, President A. I. E. E. 1935-36

After all, the officers, board of directors, and headquarters staff are only the means by which coordination is effected. It is the individual engineer who makes the Institute what it is—it is his Institute and the policies and codes formulated are merely reflections of his wishes.

The Institute has always been keenly interested in perpetuating an ideally democratic organization as opposed to dictatorship in any form or to any degree.

There is a great deal of thought being given this subject today, not only as applying to the government of peoples, but to all types of organizations as well.

Under dictatorship the authority resides in the highest officer. He grants a certain amount of control to officers next in command, who in turn delegate a less amount to lesser officers, and so on down the line until the great majority which has no authority is reached.

Under democracy the power of authority resides in the majority. It delegates a certain amount of authority to officers who are selected to serve the majority. In an organization of great size the democracy may take the so-called republican form. The smaller subdivisions of the democratic government elect delegates to represent them in a legislature or convention which formulates laws and nominates executive officers. Those elected direct from the subdivision may in turn elect delegates to meet with other such delegates from other subdivisions and so form a representative governing body for the whole.

The democratic idea is the highest ideal of government ever produced by man. It has never been fully realized, but as more people are able to understand the idea and as they outgrow the inferiority complex (which causes them to welcome the dictatorship of those inflated with their own assumed superiority and strength) the more nearly we approach democracy.

In normal times when the interest of the majority appears to be clear, progressive results are obtained without great difficulty. In times of economic stress and political upheaval, there is apt to occur a situation that brings about an abnormal solution.

When the road is not plain, when a multitude of opinions widely differing are offered on which no agreement can be reached, or when no solution of the problem is forthcoming, then comes the possibility that one individual, dominating what may be only a small group, is placed in power. This power is due to chance, not qualifications, and comes through the inertia or lack of unity of thought among the other political elements.

In a democratic organization such as the Institute the rule is from below instead of from above. The officers and directors are elected by the majority either directly or indirectly and the members of the many committees are selected to give the widest possible spread of representation.

A. R. Ellis New President of Pittsburgh Testing Laboratory

Born and raised in Pittsburgh and educated in the Pittsburgh Public Schools.

Graduated from Cornell University, Ithaca, New York, in 1905, with the degree of Civil Engineer.

Entered employ of the Pittsburgh Testing Laboratory the same year, as a laboratory technician.

Later became an inspector of engineering materials and finally became Chief Engineer, in 1910.

Manager of the New York Branch in 1917.

Assistant General Manager in 1918.

General Manager and Director in 1921.

Vice-President and Director 1929.

President and Director 1936.

Member of the following organizations: American Society of Civil Engineers; American Society for Testing Materials; American Society of Municipal Engineers; American Concrete Institute; AMERICAN WELDING SOCIETY; Technical Advisory Board of the American Institute Steel Construction; Registered Professional Engineer in New York, Pennsylvania, Ohio; Others pending; Engineers Society of Western Pennsylvania; Railway Club of Pittsburgh; Chamber of Commerce, Pittsburgh; University Club, Pittsburgh; Pittsburgh Field Club.

National Safety Congress and Exposition

The 25th National Safety Congress and Exposition will be held in Atlantic City, October 5–9, 1936.

Altogether there will be 125 separate meetings, a very important safety exposition, many demonstrations and other features.

Any member of the AMERICAN WELDING SOCIETY will be cordially welcome and extended the privileges of the Safety Congress.

Last year 100,000 persons were killed by accidents—the cost estimated to be three billion five hundred million dollars. These losses can be cut down by the application of the ideas and experience presented at the Safety Congress.

Arc Welding Course

The Milwaukee School of Engineering, Milwaukee, Wis., is offering a three months' welding operators course dealing with practical applied welding. In addition to the practical experience there will be lectures in metallurgy, welding design, drawing and blueprint reading, welding shop methods and items of a similar nature.

The Institute of Welding

Founded in 1923 as the Institution of Welding Engineers, the Institute has for its main object the advancement of the science and art of welding. Consequent to the enormous growth in the use of welding in every field of engineering, and arising out of the impetus given to welding inquiry by the Symposium on Welding held in May 1935 by the Iron and Steel Institute, the constitution of the Institution of Welding Engineers was radically amended in May 1935 to include the British Advisory Welding Council and enable it to become the central organization in the British Isles to which all interests could look for guidance in the technical problems which have already arisen and which will arise as welding is applied to a greater number of uses. The title "The Institute of Welding" was adopted as being more in keeping with the enlarged functions which the Institute now embraced involving the cooperation and collaboration of engineers, chemists and metallurgists.

Weldability is a characteristic of nearly all metals and it is already clear that this characteristic must inevitably lead to greater variation and profound alteration of structural design. Much data on all welding matters is already available in scattered form, and one of the first tasks of the Institute is to collate this information in a form which will serve as a guide to the best current practice.

The address of the Institute is 7/8 Holborn Hall, Grays Inn Road, London, W. C. 1.

Resistance Welding Magazine

A monthly magazine entirely devoted to resistance welding is now being published by La Société Sciaky, 13 Rue Ch. Fourier, Paris (13e), France. The first issue of the magazine, which is entitled "Souder," deals mainly with the Sciaky spot welders up to 400 kva, but also describes seam and butt welders. The bulletin is free of charge and contains 16 pages.

Welding Literature

The following communication was received from VDI Verlag G.m.b.H., Dorotheenstr. 40, Berlin, N. W. 7, Germany.

On the occasion of the tenth anniversary of the establishment of the Welding Committee of the Verein Deutscher

* Extracts from the president's message, presented at the opening session of the A.I.E.E. summer convention, Pasadena, Calif., June 22, 1936.

Ingenieure, we are publishing the new VDI—special volume on Welding, II, 275 figures, 27 pages. Price RM 4.50 (members Rm 4.05). The Index contains the following titles:

Research

A. Hilpert and W. Adrian. Ten Years of Welding in Germany
Willy Prox. Facts and Results in Arc Welding

Materials

J. Müller. Weldability of Steels of Higher Strength
H. Schottky. Welding Alloy Steels with High Strength at High Temperatures and with Scale Resistance
K. L. Zeyen. Welding of Steels of Higher Strength
L. Rostosky. Soldering and Welding Light Metals
E. Lüder. Welding and Soldering Light Metals
H. Kalpers. Corrosion Resistance of Welds

Methods

H. Blomberg. Tank Welding by means of the Atomic Hydrogen Process
H. Türcke. Welding in the Repair of Machines and Boilers
W. v. Bleichert. Small Machines for Arc Welding
Richard Malisius. Cutting and Welding Machine Parts
K. Schreyer. Shaping and Finishing Welded Apparatus
A. Matting. Raising the Wear Resistance of Surfaces by Welding
A. Matting. Raising the Hardness of Surfaces by Welding
A. Matting. Raising the Corrosion Resistance of Surfaces by Welding
A. Matting. Producing Overlays by Welding

Testing

E. Rüter. Strength of Specimens Cut from an Arc Welded Drum
W. Jamm and O. Weinrich. Investigation of an Arc Welded High Pressure Drum
G. Czternasty. Strength of High Strength Arc Welding

We also have issued:

1. Instruction Sheets for Welding in Machinery Construction. (Design Methods.)

Prepared by the Welding Committee of the VDI; about 44 pages, several figures, 1936, RM 1 (Members RM 0.90).

2. Lessel. New Methods for Metal Arc Welding Copper and Coppe-Rich Alloys Using a "Schlauch" Copper Electrode

41 figures, 1936. About RM 3.80.

The author has succeeded in metal arc welding copper by means of an entirely new type of metal electrode, the so-called "Schlauch" (tube) electrode, and by using types of arcs previously contrary to all good practice. The new method renders preheating of the work unnecessary.

3. Zobel. Increasing Cutting Velocities by a New Type of Flame Cutting Nozzle

About RM 2.75 (Members RM 2.50).

In the author's method the flow of gas is simultaneously measured and made visible. Systematic tests up to cutting thicknesses of $7^{7}/_{8}$ inch show the superiority of the new type of nozzle and show also a saving in cost of 50–60%.

SECTION ACTIVITIES

DETROIT

Elaborate plans are being made for the October meeting of the Section to be held on October 16th to commemorate the fiftieth anniversary of electric welding. Mr. A. Hackett of the Thomson-Gibb Electric Welding Company is assisting the Section in its plans.

MARYLAND

At the Summer meeting of the officers and members of the Executive Committee of this Section, it was decided to have an official gathering as a get-together meeting in October.

Lectures of interest to all members will be given on the third Friday in November, January, February and March at the Engineers Club in Baltimore. Subjects and speakers to be decided upon at a later date.

PHILADELPHIA

On May 18th the Philadelphia Section had an inspection trip to the plant of the Edward G. Budd Manufacturing Co.

The first meeting of the winter season will be held on September 21st at which Mr. J. W. Meadowcroft, Assistant Works Manager of the Edward G. Budd Manufacturing Company, will speak on "Modern Day Welding in the Automotive and Railway Fields."

The October meeting will be held on the 26th of the month.

PITTSBURGH

A meeting of the Pittsburgh Section was held at the Roosevelt Hotel, Wednesday evening, August 19th, at which the following officers were re-elected for the 1936–37 Season:

Chairman: E. J. W. Egger, Linde Air Products Company
Vice-Chairman: Marshall Williams, American Bridge Company
Secretary and Treasurer: J. F. Minnotte, Minnotte Brothers Company
Representative on National Board: W. W. Reddie, Westinghouse Electric & Mfg. Co.
Executive Committee:

F. M. Bernard, Westinghouse Electric and Manufacturing Co.
G. W. Petrie, Pittsburgh Piping and Equipment Company
H. G. Marsh, Carnegie-Illinois Steel Company
J. A. Warfel, Air Reduction Sales Company
J. A. Snyder, Hartford Steam Boiler Inspection and Insurance Co.

Membership Committee:

A. E. Marble, Chairman, Jones and Laughlin Steel Corp.

After the election of the above officers, the following matters were discussed and acted upon:

(1) That the Membership Committee, with A. E. Marble, Chairman, plan a drive for new and selected members. It was the opinion of those present that with the resumption of business throughout the country and the vast amount of welding being done in all fields, it should be possible to interest many in the work being done by the Society.

(2) That a Program Committee be appointed by the Chairman to aid in the selection of speakers and papers; somewhat in the order in which the work was done last season.

(3) That some thought be given, (*a*) to holding a luncheon meeting, (*b*) to advertise, or broadcast the work the Section is doing, (*c*) to invite interested visitors to meetings.

(4) That the question of trying to get welding incorporated in the City of Pittsburgh Building Code be brought up again.

(5) That some thought be given to holding a Welding Show, or Conference, in cooperation with some institution in the city.

EMPLOYMENT SERVICE BULLETIN

POSITIONS VACANT

V-69. Welding Engineer wanted. College trained man twenty-five to thirty-five years of age with experience in both gas and arc welding. Position will include training of arc welding operators, welding research, investigation of shielded arc weld rods, preparation of test specimens for specifications and qualifications. Applicants will please include recent photograph, state age, education, experience in detail, and salary expected. Replies will be held in the strictest confidence.

V-70. Wanted—A foreman and a layerout, experienced in pressure vessel and steel plate fabrication. Interview Mr. G. Raymond, Cleveland Hotel, Cleveland, October 19th to 23rd, or write Black, Sivalls & Bryson, Inc., Box 1377, Oklahoma City, Okla.

V-71. Electric Welders qualified for fabrication of A. P. I.-A. S. M. E. Code Vessels. Excellent working conditions and steady work. Include references and record of experience with application.

SERVICES AVAILABLE

A-232. Young man, 30, wishes position in the capacity of foreman or supervisor. Formerly Asst. Supervisor on U. S. Goverment work. Qualified U. S. Navy and A. S. T. M. tests. 14 years unlimited experience in repair and production work, Shielded Arc, bare wire, alloys, castings, high pressure vessels, shipyard work, both Gas and Electric. Experienced in the handling of men. Have a vast knowledge of welding, practical and theoretical that any concern interested could use to advantage.

CURRENT WELDING LITERATURE

Acetylene Explosions. Suggestion in Regard to Minimizing Risk of Explosion after Ignition of Dissolved Acetylene Cylinders, J. R. H. Coris. Welding J. (June 1936), vol. 33, no. 393, pp. 174–177. Description of burning of cylinder and results of investigation; observations on wall of cylinder; examination of escaping gas and of pressure regulator; chemical analysis of porous material; investigation of contents of cylinder; cause of fire; explanation of phenomena observed. Bibliography. Before XIIth Int. Congress of Acetylene, Oxyacetylene Welding & Allied Industries.

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Aluminum. Recent Progress in Welding of Aluminum and Its Alloys, J. Douchement. Aluminum & Non-Ferrous Rev. (May 1936), vol. 1, no. 8, pp. 391–396.

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Chemical Equipment. Welding Chromium Steels in Chemical Plant Equipment, J. R. Dawson. Chem. Age (Mar. 7, 1936), vol. 34, no. 871, pp. 15–17. Correct procedure to follow.

Dam Construction. Grand Coulee Construction Work Speeded with Use of Welding and Cutting, H. W. Young. Welding Engr. (June 1936), vol. 21, no. 6, pp. 28–30.

Electric Vs. Oxyacetylene. Oxyacetylene Vs. Electric Arc Welding, M. R. Meslier. Foundry Trade J. (June 18, 1936), vol. 54, no. 1035, p. 490. Examination and comparison of results obtained by arc and oxyacetylene processes when used in accordance with established technique for making butt welds on steels in common use. Before XIIth Int. Congress of Acetylene, Oxyacetylene Welding and Allied Industries.

Electric Welding. Welding Metals without Fusion, by "Molecular Shock," A. H. Allen. Steel (June 22, 1936), vol. 98, no. 25, pp. 34–36.

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Gas Pipe Lines. Rejuvenating City Gas Distribution Systems. Oxy-Acetylene Tips (Aug. 1936), vol. 15, no. 8, pp. 182–183.

Industrial Plants. Welding Builds a Factory. Eng. News-Rec. (July 16, 1936), vol. 117, no. 3, pp. 90–93. Details of all-welded construction of plant at LaGrange, Ill., manufacturing Diesel locomotives, including main building 550 ft. by 170 ft. and eight other buildings; structural details of welded trusses, columns and crane girders; largest welded crane yet built carries four 50-ton hooks and two 15-ton auxiliaries.

Iron and Steel Plants. Oxygen Lance. Oxy-Acetylene Tips (Aug. 1936), vol. 15, no. 8, pp. 173–178.

Motor Truck Manufacture. Varied Welding Operations Assist Production of Motor Trucks, F. B. Jacobs. Steel (July 13, 1936), vol. 99, no. 2, pp. 32–34. Welding practice of White Motor Co., Cleveland, Ohio.

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BOOKS

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Svarnye Konstruktje. Structural Welding. A collection of translations edited by Asst. Prof. B. N. Duchinko and Prof. G. A. Nikolaev, 1936. 160 pages. Although most of the 14 translations are from German periodicals the list includes the Structural Steel Code for the AMERICAN WELDING SOCIETY (A. W. S. JOURNAL, 14, 1935 (5)), the Australian Rules for the Design and Construction of Metal Arc Welding in Steel Buildings (A. W. S. JOURNAL, 13, 1934 (7)), The New Polish Welding Regulations (A. W. S. JOURNAL, 13, 1934, (7)), "Fatigue of Metals," by G. Thornton (A. W. S. JOURNAL, 13, 1934 (3)), and "Boulder Dam Cylinder Gate and Nose Liner Welding Problems," by C. Jennings (A. W. S. JOURNAL, 13, 1934 (5)).

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"HELPS TO KEEP PEOPLE CLOSE AND FRIENDLY"

"I put through a call for my son down East. Must be three hundred miles.

"'Hold the line,' the operator said. And next thing you knew, there he was. Sounded just like he was right here. It wasn't like that when I was a young fellow."

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THIS COUNTRY has the best telephone service in the world. And it's still getting better—quicker, clearer, more useful to more people. Each year brings improvements in equipment and operating efficiency. Operating errors on local calls—always a small percentage of the millions handled daily—have decreased 40% in the past six years.

Since 1929, the average time required for long distance connections has been reduced from 2.8 to 1.4 minutes and 92% of these calls are now handled while you remain at the telephone.

Time has proved the value of the Bell System plan of operation—"One policy, one system and universal service."

BELL TELEPHONE SYSTEM